U. S. Geological & geographical survey of the territories

PRELIMINARY REPORT

OF THE

FIELD-WORK OF THE UNITED STATES GEOLOGICAL AND GEOGRAPHICAL SURVEY OF THE TERRITORIES,

UNDER THE DIRECTION OF PROF. F. V. HAYDEN,

FOR THE SEASON OF 1877. — 1878

OFFICE OF THE UNITED STATES GEOLOGICAL AND
GEOGRAPHICAL SURVEY OF THE TERRITORIES,
Washington, D. C., December 1, 1877.

SIR: I have the honor to submit the following preliminary report on the operations in the field of the Survey under my charge during the season of 1877.

On the completion of the survey of Colorado last year, it was determined that the work of the United States Geological and Geographical Survey of the Territories under my direction should continue northward into Wyoming and Idaho. The belt of country including the Pacific Railroad having been explored and mapped in detail by the Survey of the Fortieth Parallel, under Clarence King, esq., it was deemed best to commence at the northern line of that work, and continue northward and westward, taking for the season of 1877 the country from Fort Steele, Wyoming Territory, to Ogden, Utah, or, more exactly, from longitude 107° to 112°, and northward to the Yellowstone Park.

The primary-triangulation party, in charge of Mr. A. D. Wilson, Chief Topographer of the Survey, took the field from Rawlins Springs, Wyo. Near this point a base-line was measured with great accuracy, from which a net-work of triangles was extended over the country to the north and west, locating, at intervals of from twenty to thirty miles, some prominent peaks, upon which stone monuments were built, in order that the topographers could recognize the points thus fixed for them. Upon these points was based the system of secondary triangulation.

From the base at Rawlins, the work was carried northward to the Sweetwater Mountains, and thence to the Wind River Range. Upon some of the more prominent peaks of the latter range, such as Frémont's Peak, the stations were made with much difficulty, owing to the great masses of snow found there during the month of June, when the party was working. From this range the work was carried across the Green River Basin to the mountains on the west and north, where several stations were made. The work was resumed to the west as far as Fort Hall, Idaho, and thence south to the vicinity of Bear Lake, where another base, or base of verification, was measured; thence south as far as Ogden and Evanston, connecting with the triangulation of the Fortieth Parallel Survey at these points. From Evanston the party marched eastward, making some stations north of the railroad, thus bringing the work back to the point of beginning, Rawlins Springs, where the party was disbanded for the season. The system of triangulation employed during the past season was essentially the same as that carried over Colorado.

The triangulation is all-important, as the topographical work depends entirely upon it, and the geologist can do but little without an accurate map. Thus the topographical as well as the geological maps are dependent upon a good system of primary triangulation.

In addition to the primary-triangulation party already referred to, there were three fully equipped divisions for topographical and geological work, and another, under the direction of Dr. C. A. White, for critical palæontological work.

The area assigned to the Green River division, under the direction of Mr. Henry Gannett, was rectangle No. 56, which is limited on the east and west by the meridians of 109° 30′ and 112° and on the north and south by the parallels of 43° and 41° 45′. This is an area of about 11,000 square miles, lying in parts of Wyoming, Utah, and Idaho. The party took the field at Green River City, Wyo., on June 1. They first surveyed the drainage of Green River Basin. For this purpose they traveled up the Big Sandy, a large eastern branch of the Green, to the foot of the Wind River Mountains; thence crossing the head of the basin, fording the large and rapidly rising streams which make up the New Fork of the Green, they reached the main Green, and traveled down its western bank, going in to Granger, Wyo., on the Union Pacific Railroad, for supplies on June 23.

The Green River Basin is a broad, flat, almost unbroken expanse, covered mainly with sage, among which considerable grass is scattered. Its greatest width in this district is about 50 miles, and its length reaches nearly a hundred. Its area within the district is not far from 3,000 square miles.

The river-bottoms of the Green and its branches, excepting the Big Sandy, are everywhere broad and beautiful, well covered with grasses, and shaded by magnificent groves of cottonwood. For agricultural purposes these bottom-lands are very valuable, while the limitless expanse of bunch-land would afford grazing to enormous herds of cattle. The Big Sandy is in low cañon through most of its course.

Leaving Granger, the party next surveyed the broken, hilly country lying between the basin and the upper course of Bear River, north of Harris's Fork. Following this belt northward, these hills develop into mountains of considerable importance about those large branches of the Snake known as John Day's and Salt Rivers. The party surveyed this belt northward to the north line, whence, turning westward, they mapped the basin of the Blackfoot and the valleys of the Portneuf; thence going in to Fort Hall, early in August, for further supplies of provisions. Taking up this section of the district in the order in which it was worked, it will be noted that the valley of Harris's Fork is fine agricultural land; that the hills about its head, separating it from the Bear, are rounded and grass-covered, affording a magnificent stock-range. As the hills increase in size and assume the dignity of mountains, the grass gives place to heavy pine and spruce timber of fine quality. John Day's River flows in a cañon valley, heavily timbered. The valley of Salt River is nearly ten miles in width and of the finest quality of land. West of this valley are high, broken hills, separating Salt River from the Blackfoot. The latter stream pursues a devious course in a great plain of basalt, diversified by buttes and extinct craters. Along the river are fine meadows, alternating with large swamps. The whole basin is covered with the best of grass.

West of this basin the Blackfoot is separated from the Portneuf, here flowing south, by a range of low, grass-covered hills. The valley of the Upper Portneuf is at least eight miles broad, and is valuable for agriculture or grazing. West of it is a high range of mountains, through which, lower down, the Portneuf cuts its way into another broad valley, in which it flows to the north. This valley is floored with basalt, and is almost valueless.

From Fort Hall the party proceeded to survey the country drained by the Bear and its tributaries, proceeding generally from the east westward. The country is a succession of parallel valleys, separated by ranges of bare, grass-covered hills or timbered mountains. The most eastern of these valleys is on the upper waters of the Bear. It is nearly ten miles wide, of good soil, and easily irrigated. The only drawback to agricultural pursuits is the elevation, 6,000 to 6,500 feet, which, in this latitude, indicates severe winters.

Next westward is Bear Lake Valley. Here the cultivable area is at the head and foot of the lake, besides a narrow strip on its west border. Below the lake, the valley extends on to the northward for many miles down the Bear, and is very broad and fertile. The elevation of this valley is 5,500 to 6,000 feet.

Further westward we encounter the Bear River Range, a broad belt of mountains reaching nearly to 10,000 feet in height, and heavily timbered. Beyond is Cache Valley, one of the finest areas of farming-land west of the Missouri. The elevation is 4,500 to 5,000 feet. Besides grain, nearly all garden-vegetables and many fruits are raised in this valley.

A broken range of mountains separates this valley from that of the Malade. The latter has about the same elevation as Cache Valley, and is almost equally fine. Beyond it is a range of grass-covered hills, separating it from Blue Creek Valley.

The valleys of the Bear are peopled mainly by Mormons; very few Gentiles indeed are to be found there. Mormon settlements, of greater or less extent, are to be found all along the Bear, from its mouth nearly to Randolph. Malade Valley is but sparsely settled as yet. Cache Valley contains several good-sized towns; the eastern part of the valley is quite closely settled. The valley of Bear Lake contains several good-sized towns, but above that settlements are scarce.

The party left the field at Ogden, Utah, on September 30, having been in the field just four months. The area surveyed was between 12,000 and 13,000 square miles; 347 stations and locations were made; 53 of the stations, being important ones, were marked with stone monuments for future reference.

The geological work of Dr. A. C. Peale in the Green River district connected directly with the eastern edge of the Sweetwater district.

With the exception of a small area of granite along the southwestern side of the Wind River Mountains, and some basaltic flows in the northwestern portion of the district, the rocks are sedimentary, including the rocks from the Carboniferous to very late Tertiary age.

The first month of the season was occupied mainly with the survey of the Green River Basin. Leaving Green River City, the river was followed to the mouth of the Big Sandy, a shallow, muddy stream, rising in the southwestern slopes of the Wind River Mountains. Both on Green River and the Big Sandy the prevailing formation is the Green River Tertiary group, consisting of clays, marls, and calcareous sandstones, forming bluffs on the rivers. These [strata continue uninterruptedly westward, inclining eastward from the hills west of Green River. Toward the southern part of the district remains of the Bridger clays are seen, forming buttes on the Green River beds. They are the outlines of the extensive Bridger areas that extend southward. On the southwest slopes of the Wind River Mountains there are abundant evidences of comparatively recent glacial action.

The next area taken up was that lying between Green River and the Bear, with a strip along the northern edge of the district, reaching westward beyond Fort Hall.

The mountains west of Green River are composed mainly of Carboniferous limestones. Toward the north they form two beautiful ranges on John Day's River and Salt River, separated by a valley in which rocks of Jurassic and Cretaceous age outcrop. Between the mountains and the Green River Basin is a range of hills of Jurassic and Cretaceous age. On the east of these is the Wasatch group of Tertiary, resting unconformably on the Jurassic hills. Farther north the Wasatch beds cover the Jurassic and Lower Cretaceous strata, extending partly over the Laramie Cretaceous, with which it is unconformable. Carboniferous fossils were obtained from limestone bowlders in a conglomerate at the base of the Wasatch. These were derived, without doubt, from the Carboniferous mountains to the westward, which formed the shore-line of the ancient lakes in which these beds were deposited. An arm of this lake extended up Harris's Fork of Green River. The Green River and Wasatch beds here are horizontal, the former containing abundant remains of insects and fish. Good collections were obtained at several localities.

The region of the Blackfoot River, in the northern portion of the district, is covered in the lowest portions with flows of basalt. These had their origin between the Blackfoot, Bear, and Portneuf Rivers. A number of the craters still remain. One of these, south of the Blackfoot, is very distinct, rising 200 feet above the general level. It is about 130 yards in diameter, and has a circular depression on the summit. The pouring out of this basalt must have occurred either during or immediately prior to our present period, as there has been little if any change in the surface since the eruption.

The Blackfoot, Portneuf, and Bear all have the basalt in their valleys. On the Portneuf it extends almost to the Snake River plain, showing as a narrow belt. Its surface slopes, but not so much as the present bed of the stream. In some places the volcanic rock appears to have pushed the river to the western side of the valley. The lower valley of the Portneuf is interesting from the fact that it is the probable ancient outlet of the great lake that once filled the Salt Lake Basin. At the head of Marsh Creek, which occupies the valley, continuing directly south from that of the Lower Portneuf, is the lowest pass between the Great Basin and the drainage of the Columbia. In fact, so low and flat is it that a marsh directly connects the two streams, one flowing to the Bear and the other to the Portneuf and Snake Rivers.

The bend of Bear River at Soda Springs is one of the most remarkable features of the whole district. Rising in the Uintah Mountains, Bear River flows northward for over two hundred miles, and at Soda Springs bends abruptly and flows southward toward Salt Lake. After it emerges from the gap west of Soda Springs, it flows out into a wide valley which opens directly into that of the Upper Portuenf. In this valley the divide between the two rivers is only a basalt plain, and in the eruption of this lava we may look for the clew to the extraordinary course of Bear River.

North of the bend of Bear River the mountains consist of isolated masses of Jurassic and Carboniferous rocks, the general strike of the rocks being northwest and southeast. There are several interesting folds in the rocks of this region.

The interesting springs at Soda Springs were carefully examined.

The latter half of the season was devoted to Bear River, Bear Lake, and Cache and Malade Valleys.

The Upper Bear River Valley has a wide drift-covered bottom. The hills on the east side soon develop into mountains as we go north. Formations from the Carboniferous up to the Wasatch Tertiary are represented, the latter resting on the upturned edges of the older rocks. On the west the same unconformability is seen, the area of Wasatch extending farther north. The beds consist of variegated sandstones and conglomerates. Bear Lake Valley has a range of low hills on the east, at the foot of which the lake leaves but a narrow margin. The waters of the lake occupy an area that is probably underlaid by several folds.

The Bear River Mountains are composed of Silurian and Carboniferous rocks, limestones, and quartzites. The edges of the strata face the east, but as we go west we soon cross a synclinal fold, the western side of which rises into high peaks on the east side of Cache Valley. The base of the range facing Cache Valley is Silurian. It is abrupt, and the basset edges of the strata give it extreme ruggedness. In the cañons of the streams coming from the range, saw-mills have been erected, and now supply the flourishing towns of the valley. Numerous lime-kilns also furnish them with a good quality of lime, the limestone being derived from the adjacent rocks.

There is but little doubt that the waters which once filled the Salt Lake Basin covered also the broad Cache Valley. The modern Tertiary deposits are found jutting against the mountains, and seem to pass gradually into the more recent deposits found in the central portion of the valley. The clays, sands, and marls of these modern beds are beautifully exposed along Bear River, which cuts its way across the northwestern part of the valley. On the west the mountains are broken or isolated ranges, which seem to have risen above the waters of the old lake as islands. The terraces are well marked on their sides, connecting with the Salt Lake Valley through the gap of Bear River.

West of this gap, and extending northward, is the Malade Valley. It is broad and filled with modern lake deposits. Silurian rocks outcrop on the east and Carboniferous on the west. At the divide between the Malade and Marsh Creek is another of the old outlets of the ancient Salt Lake when its waters were at the highest level. Although the area surveyed was large, (13,000 square miles,) good collections of fossils were made and data obtained for the elucidation of many interesting problems in relation to the age of the mountains. The entire district is of great interest to the geologist. Coal-outcrops were noted at a number of places on the Upper Bear River and its tributaries, and on some of the branches of Green River.

At one locality between Twin Creek, a branch of the Bear, and Harris's Fork, a tributary of Green River, there are some twenty-nine coal-beds, separated by sandstones and clays, the aggregate thickness being 315 feet. The beds of coal are from 1 foot to 48 feet thick. This locality has been called the "Mammoth Vein."

The area allotted for examination to the Sweetwater division, under the direction of Mr. G. B. Chittenden, covering atlas-sheet No. 57, is bounded on the east by the meridian 107°, and on the west by that of

109° 30′ of west longitude, and on the north by the parallel of 41° 45′, and on the south by that of 43° of north latitude, embracing a district of about 10,800 square miles.

In working this area, 171 principal topographical stations were made, besides some twenty auxiliary ones not numbered in the regular series. Between eighty and ninety stone monuments were erected on these stations to mark them permanently, while the peculiar topographical features of a great many others mark them with equal distinctness. While many of these, owing to the extremely desolated character of the country surveyed, are not likely ever to be used as initial points for the rectilinear surveys, there still will be many others which will be of very great value in giving starting-points for isolated pieces of rectilinear work, where fertile valleys and oases in this desert country are rapidly coming into demand by the settler. The most important of these fertile tracts are on the great southern drainage of the Wind River; the whole of the Sweetwater, with its southern tributaries; Sand Creek; the drainage of the old Seminole mining-district, and a series of lakes and springs south of the Sweetwater, near the latitude of Saint Mary's Station.

Into the first two of these districts (or a portion of them) a rectilinear survey was pushed this season by the measuring of a guide-meridian from the railroad, north, and the establishment of base-lines within the district. The guide-meridian had to be measured over about seventy-five miles of broken desert country, where water was extremely scarce and found only at long intervals. In the vicinity of all these fertile districts, particular pains were taken to give permanent markings to the topographical stations, and connections were made on two of the guide-meridian stakes, distant some forty miles from each other.

In continuance of the summer's work, the party took the field from Salt Wells Station, on the Union Pacific Railroad, on the 1st day of June, and completed the topographical work on the 25th day of September, in the vicinity of Fort Steele. Owing to orders, received at the beginning of the season, to complete the field-work by the 1st of October, and the very doubtful safety of a tract of low country in the northeastern portion of the district, an area of about 800 square miles was necessarily left unworked in that portion of the district. The total area worked by the party, as nearly as can be estimated before the final plat is made, was 10,000 square miles. Careful notes were made on the grazing facilities, timber, and irrigability of the whole district, which will be more fully given in a later report. Taken in masses, an estimate of this area shows five-eighths to be desert country, two-eighths mountainous, and the remaining eighth valuable land. Giving these figures before the plat is made, they are of course merely estimates, but will afford an idea of the general characteristics of the country.

The weather throughout the entire season was much colder than that experienced at the same altitudes in Colorado, but the party suffered much less from rain, and in the four months of field-work did not lose one single day from bad weather, or indeed from any cause.

Dr. F. M. Endlich, Geologist of the Sweetwater division, states that within the area described above he found a well-diversified country.

A portion of the Wind River Mountains, in the northwest corner; the Sweetwater and Seminole Hills, toward the eastward, in addition to the lower bluff-country in the southern portion, furnished material at once full of interest to the student and to the surveyor.

After having surveyed that portion of the Green River drainage which lies immediately outside of the mountains, the first halt was made at Camp Stambaugh. The party until then had passed through a region containing none but Tertiary formations. But little variation was found in the arrangement of strata, as well as in the distribution of fossil remains. Isolated volcanic eruptions of small dimensions produced prominent bluffs, far visible. These formed excellent landmarks, and were duly utilized as such. From Stambaugh, the party turned its course southward toward the Union Pacific Railroad. Here, too, the regular succession of Tertiary strata prevailed. The readily-disintegrating sandstones of the region have given rise to the formation of very extensive sand-dunes. It may be observed that westerly winds are prevalent throughout that section of country, and, as the result thereof, we find them driving the sand to leeward and depositing it wherever the configuration of the country presents any obstacle to its farther progress. In this manner a "belt" of sand-dunes, about ten miles wide and fifty miles long, has been formed. Some difficulty was here experienced, occasioned by the sparing distribution of water. Only in springs and small alkaline lakes could it be obtained.

Red Desert Station, on the Union Pacific Railroad, was the point reached June 18. From there the party moved northward again toward Stambaugh, which place was reached July 3. Stambaugh is located within the area of the oldest metamorphic rocks of the district. In these metamorphics gold has been found during the last ten years in varying quantities, and the region was at one time the scene of considerable mining excitement. At present the mines have been to a great extent abandoned, and but little activity is noticeable.

Snow still covered a large portion of the Wind River Mountains, and it was deemed advisable, therefore, to carry on the explorations in some lower country until, late in the season, the mountains should be more accessible.

On July 5 the party left Stambaugh and marched toward the low valleys belonging to the Wind River drainage. The difference in elevation amounted to about 3,000 feet, and the temperature of the atmosphere was consequently much higher. While all the surroundings of the post were totally useless for agricultural purposes, the valleys of the Popo-Agies and their tributaries contained excellent farming-land. In spite of continually threatened raids by the Indians, a large number of settlers have taken advantage of the good soil and mild climate. With the change of elevation the geological formations change. Instead of the youngest beds resting directly upon the metamorphics, we now find a full series of the sedimentary formations, beginning with the Silurian. Numerous interesting stratigraphical phenomena were observed and studied with a view to determine their relations to the main mountain-chain. An ample amount of evidence has been obtained, more particularly by this means, to speak positively respecting the geological age of the Wind River Mountains. These latter, in this region, form the main Rocky Mountain chain, and the determination of their age will necessarily throw much light upon the same question arising in other portions of the same range. It will be possible to speak with a certain degree of precision of either the local, varying (as to time) elevation of the mountains or to refer it to one particular epoch for the distance of many hundreds of miles.

Camp Brown is located in the valley of the Little Wind River, which there is of considerable breadth. The famous hot springs there were examined. As the main peaks of the Wind River Mountains were mostly inaccessible from the east side, it was deemed advisable to make the ascents of the highest from the west. Therefore the party traveled along the eastern foot-hills, through a very rugged country, until Stambaugh was reached.

July 22 the party again left Stambaugh and marched along the headwaters first of Sweetwater River and then of the eastern tributaries of Green River. Several of the highest peaks were ascended, and the greatest altitude reached found to be about 13,700 feet. This latter was on what the settlers generally designate as Frémont's Peak. From careful comparison of Frémont's report with the observations made by the party, it is evident that a misapplication of the name has been made, and that the peak in question is not the one ascended by that intrepid explorer of an "early day."

Having reached the northern limit of the district, the route was reversed and the western foot-hills of the main ranges examined. Here, as well as in the mountains proper, were noticed the remains of enormous ancient glaciers. Moraines, covering many square miles, often a thousand feet in thickness, extend downward through narrow valleys, now containing rushing streams. Striation, grooving, and mirror-like polish of rock *in situ* denote the course taken by the moving ice-fields that have left these marks of their former existence. From all appearance the cessation of glacial activity must have occurred within a comparatively recent time. Scarcely any vegetation has sprung up on the light glacial soil, and the characteristic distribution of erratic material bears every evidence of "freshness." Considering the enormous amount of snow and ice that was observed by the party exploring, (latter part of July and beginning of August,) the view was expressed by the geologist that the discovery of still active glaciers in that range would by no means be surprising.

Returning for the last time to Stambaugh, the route was taken in an easterly direction along the Sweetwater and its drainage. First, the adjacent drainage of the Wind River was surveyed, and the divide between the two streams crossed. All along the Sweetwater the characteristic "Sweetwater group" of Tertiary age was found to occur. It has been named and described in my former publications. This continued uninterruptedly until a series of hills north of the river, opposite Seminole Pass, was reached. These consist merely in projections of granite that during the Tertiary epoch, and probably long before that, had remained as islands above a widely-extended sea. Apart from their singularly unique character in this respect, the granite itself possesses a peculiarity that renders it at once conspicuous. Owing to the distribution of component minerals, this granite is in a high degree subject to exfoliation. Probably the main cause of this may be found in the action of freezing water. The result is striking. Instead of the rugged outlines usually presented by isolated granitic outcrops, we find a series of rounded, smooth, almost totally barren hills. To such an extent is this feature developed that many of them offer serious obstacles to ascent. A locality where the celebrated moss-agates occurred in great quantities was found in that region, and the geognostic horizon of these interesting quartz varieties was established. Marching southward, the party crossed the Sweetwater, and in the Seminole Hills once more encountered older sedimentary formations. Disturbances of enormous dimensions have here taken place, and render the study of the range one of extreme interest.

On August 29 Rawlins was reached and the provisions for the following month taken. From there the course lay northward, through low, dry country, where several alkali-lakes furnished water. Between two of these, a short distance apart only, a rare occurrence was observed. Mud-springs, analogous to the mud-puffs of the famous Geyser region, covered about two square miles. Some of them were extinct, but most of them were still in action. By some force, which will not be here discussed, the water is caused to enter cylindrical orifices of varying dimensions. Inasmuch as this water contains in solution a large amount of mineral substances, and there is suspended in it a very large quantity of fine clay, evaporation produces a deposition of these materials. In this manner a cone is gradually raised, consisting of slightly arenaceous clay. So long as the force acting upon the water is more than adequate to the height of the cone, there will remain a circular opening at the top of the latter. When, however, this ceases, the result is simply a mound. About four hundred of these curious springs were found and examined. Great care was requisite, as the soil is very treacherous, and a mud-bath inevitable in case of breaking through.

The Sweetwater and Seminole Hills were examined during this trip and found to afford ample material for study. Stratigraphically considered, they may be regarded as being among the most interesting portions of the district. A satisfactory distribution of fossils in the various formations permitted all difficulties to be readily interpreted.

September 17, Dr. Endlich left the party and proceeded to examine the coal-bearing series and the mines near Evanston, Wyo. This was done with a view to present at an early date a report upon a subject which now has become one of vast importance.

On September 22 the party reached Fort Steele, and, having completed the work of the season, disbanded. Its members returned to Washington, there to prepare the maps and reports of the summer's work during the coming winter. Over 10,000 square miles were surveyed topographically and geologically during the time occupied in the field. Notes were obtained upon the geology, for the preparation of a geological map, and upon the agricultural and mineral resources of the district explored. A collection of Coleoptera and Diptera was made as complete as time would permit.

The district assigned to the Teton division, directed by Mr. G. R. Bechler, was situated between the parallels 43° and 44° 15′ of north latitude and the meridians 109° and 112° of west longitude. This area is drained by the branches of Shoshone or Snake River. The first portion surveyed by this division lies along the Blackfoot River and its tributaries. There are also some branches of Snake River, as Salt, McCoy, John Gray's, Fall, Antelope, Big Sandy, and Willow Creeks. Along the north side, and parallel to the Blackfoot River, is the Blackfoot range of mountains, with its higher portions toward the west, fronting the great plain of Snake River. In its southeastern continuation, near Gray's Lake, this range is reduced to a height of not more than 700 feet above the general level, so that it forms a low plateau divide; but south of Gray's Lake it rises until it attains a height of about 8,000 feet, about the sources of the Salt and Blackfoot Rivers.

Along the southwestern border of Shoshone or Snake River stretches another mountain ridge, reaching its highest point to the eastward, near Salt River, but diminishing in height as it follows along the lower cañon of Snake River, until it assumes more the character of a plateau, and finally terminates, near the Crater Butte bend, in a flat, terraced country.

Within this district Mr. Bechler made thirty topographical stations, over an area of about 10,000 square miles. There is in this district a considerable amount of timber, mostly pine and poplar, (quaking aspen,) with a fair average of arable and grass land. The streams contain running water, even in the driest portions of the year. This region is especially adapted to stock-ranches, and must soon be occupied by herds of cattle.

After having completed the area described above, Mr. Bechler returned to Fort Hall for supplies, and then passed up Henry's Fork to the northern portion of the Teton Mountains, where he spent several weeks investigating this snow-covered range; then, crossing Pierre's Basin, surveyed the lofty group to which in 1872 he gave the name of Pierre's Hole Mountains. These ranges are characterized by as great ruggedness and inaccessibility as any other mountains in the Northwest.

During the past season the waters of Snake River and its tributaries were extraordinarily high, owing to an unusual amount of snow in the mountains, so that the party experienced much difficulty and loss of time in crossing the various streams. The fording of Snake River has always been difficult at all seasons of the year. The Snake and Grosventre Rivers flow through a broad and beautiful basin or valley, which separates the Teton from the Grosventre Range. The trend of the latter is southeast and northwest, nearly at right angles with the Teton group. The Grosventre Range, with the other parallel ranges to the south, of which Salt RiverRange is one, forms the dividing barrier between the waters of the Columbia and Green Rivers.

Fronting the Grosventre Range on the north rises another mountain cluster, separated from the former by the Grosventre River. This range forms the divide between the latter river and the Buffalo Fork of the Snake. It connects with the main Rocky Mountains near the sources of Wind and Grosventre Rivers and the Buffalo Fork of the Snake, and culminates near its western end in Mount Leidy. Mr. Bechler occupied two weeks in a careful survey of a part of the Grosventre Range, the entire Mount Leidy group, with the Upper Snake River Valley and its numerous interesting features.

North of the Buffalo Fork of the Snake, his observations extended into that densely wooded mountain region which connects to the north with the Mount Sheridan group, near the Yellowstone, Lewis, and Shoshone Lakes.

About the 1st of September he left the waters of Snake River, and marched along the rugged and densely timbered mountain spurs toward the Upper Wind River Pass, and, after crossing the latter, entered Wind River Valley, having the Owl Mountains on the left and the Wind River Range on the right. As he was about to cross over the Warm Spring Pass of the Wind River Mountains into the Green River Valley, to survey the southern ends of the Grosventre and Salt River Ranges, he received a notice, through Indian scouts, from the commander of the military post at Camp Brown, to leave the country, on account of the danger of hostile Indians. On this account nearly a month of valuable time was lost, abridging somewhat the results of the season's work. Notwithstanding the various difficulties which this party encountered, they surveyed an area of about 6,000 square miles of the most rugged mountain country in the Northwest, and made one hundred and ten reliable observations with the mercurial barometer. Mr. Bechler, throughout his district, personally observed 7,340 horizontal angles and 5,700 angles of elevation and depression; and as they reported backward and forward, and were checked by good barometric readings, they must give satisfactory results as to the altitude of that extremely mountainous country.

The following is a summary of the results of the geological investigations of Mr. Orestes St. John, geologist of the Teton division:

Commencing with the area assigned to the Teton division of the survey at its southwestern corner, the first five weeks were devoted to the examination of the region lying in the great northern bend of the Snake River, and which includes an area of 1,700 to 2,000 square miles.

This section consists, topographically, of a series of more or less parallel low mountain ranges, of which the three principal ones are, the Mount Putnam Range, on the southwest, and which extends southward into the adjacent district; the Blackfoot Mountains, in the central portion; and the Caribou Range, which embraces a rather wide belt of broken hill country and low mountains along the eastern border, and which culminates in Mount Bainbridge. These ranges have a general direction west of north and east of south, and are separated by broad, shallow depressions, in the midst of which occur other lesser parallel ridges. To the north these low ranges die away in the great plains of the Snake Basin, which comprise about one-third the area of the section here referred to.

The Snake plains are everywhere floored with basaltic rocks, which were met with in the extreme southwest portion of the district, along Ross Fork, at the western foot of Mount Putnam. To the northward, in the debouchure of Blackfoot River, these rocks rise high up on the flanks of the hills bordering the plains, where they attain elevations of 600 to 800 feet or more above the level of the plains, toward which they incline in great benches or foreland slopes. Similar occurrences of basalt are found at various points along the northern border of the hill country; the northern termini of the Blackfoot and Caribou Ranges exhibiting similar benches, inclining in long, gentle slopes to the general level of the Snake plains. These basaltics penetrate all the principal valley depressions opening to the southward, forming extensive inlets which occupy ancient valleys of erosion in the sedimentaries. The Blackfoot Valley and the valley depressions between the Blackfoot Mountains and the Caribou Range are floored with basaltics in every way similar to the deposits occurring in the Snake plains, and which extend up these valleys to the southern boundary of the district, flooring wide, basin-like expanses into which these depressions open out toward their sources. In this manner the Blackfoot Mountains are surrounded, as it were, rising in the midst of a basaltic sea, as also is the case with other sedimentary ridges in this region.

The vertical extent of these basaltic flows, which doubtless represent several distinct epochs of eruption, it is impossible to decide with any degree of accuracy, though they are here seen to reach a thickness of several hundred feet. The extent to which they have suffered erosion is enormous, for it is undoubtedly true that they once in many places reached high up on the flanks of the insular mountain ridges, but where to-day not a trace remains to show their former presence. Yet there are a host of phenomena bearing on the present occurrence and extent of these deposits which require thorough examination into before we can present even a general statement of the facts which may finally lead to the elucidation of the history of this member of the volcanic series in this region.

These basalts extend up the valley of the Snake as far as the lower basin, where they are succeeded by other volcanics. These latter, mainly trachytic materials, are far less conspicuous in the area of their exposed occurrence than the basalts, and are usually met high up on the sides, and even crowning some of the highest mountain crests. They are always observed to incline at greater or less angles, and when seen in the ridges along the northern border of this region, they dip in the direction of the Snake plains. They appear to be more ancient than the basalts, their connection with which cannot now be clearly determined. Toward the northern terminus of the Caribou Range, in some of the highest crests in that quarter, these deposits are seen to be underlaid by a heavy mass of water-worn bowlders and pebbles, cemented with a fine paste. This deposit is not clearly stratified. And again, within the lower basin of the Snake, (that marked "prairie-bottom" in 1872 map,) similar pebble deposit is imbedded with alternations of laminated trachytics and compact lava-basalt, which together make up a thickness of several hundred feet, gently inclining toward the center of the valley, forming a sort of low foreland along the base of the mountain, against which the volcanics abruptly impinge. In the valley of the Blackfoot, where the party met with isolated areas of trachyte, a heavy mass of conglomerate of a similar appearance occurs, associated with sand, and dipping in the east side of the valley at a moderate angle toward the Blackfoot Mountains. It differs, however, from the before-mentioned bowlder-bed in being made up of a greater variety of more or less abraded material, including pebbles of trachyte and lava-basalt, indicating its more recent origin.

Rhyolitic and other volcanic products were found at a few localities in the region. In one instance the eruptive matter appears as a dike in the crest of a low, short ridge (station 17) between the Blackfoot and Caribou Ranges, its eruption having tilted the sedimentary deposits into an anticlinal ridge. Again, in Mount Bainbridge, (station 28,) very interesting phenomena were observed in connection with these rocks. The mountain is a monoclinal ridge, made up of sedimentaries, between whose strata the igneous matter is intruded, appearing like veritable beds of deposition, seen from a distance, while the bulk of the west portion of the mountain appears to consist of an enormous mass of eruptive matter thrust up from below. Mount Bainbridge would seem to be another instance of local outburst of volcanic material similar to those brought to light by the survey in Western Colorado. In the course of the prosecution of the examinations in the volcanic rocks of the district as complete suites were secured of the various kinds of these rocks as it was practicable to transport, and which, together with the notes, will afford the materials for an interesting chapter on this subject.

The Mount Putnam Range proper is a monoclinal ridge, made up of ancient quartzites and slaty schists, followed by Quebec and Carboniferous limestones, dipping generally to the eastward. The angle of inclination is very variable, as is also the strike of the strata. In the high peak on which station 1 was located the mass of the strata is quartzite, which in places stands vertical or even overturned and dipping westerly at a steep angle. These rocks, together with the schistose beds, constitute the exposed ledges occurring in the western side of this mountain, while to the east, doubtless, the Silurian and Carboniferous beds successively appear in the lower declivities. But in the low ridge which forms the northern extension of the Putnam Range proper these ancient quartzites gradually pass out into the plains, where they are eroded and concealed beneath detrital accumulations and late volcanic Tertiary, (the latter described by Bradley;) while the ridge itself, as its trend curves more and more round into the northeast, is crested, first, by the Quebec limestone, and then by Carboniferous limestones, followed by obscure exhibitions of the Triassic, and finally the Jurassic deposits. All these deposits in this quarter succeed each other with apparent regularity, with dips generally varying from 25° to 45°, but the strike gradually passes more and more to the west of north as we pass along this ridge in that direction, and which, together with evidences of extraordinary local disturbance, is still more manifest in the low range of hills next east and lying between Lincoln Valley and Blackfoot River.

This latter region embraces a belt of low hills and ridges which culminate to the north in Higham's Peak. Its northern extremity is covered by the upraised volcanic, through which the Blackfoot has cut a deep cañon, in which these latter deposits are finely displayed. As it will have inferred from the foregoing brief notice of the distribution of the volcanics, the basalts occur all along the eastern flank of these hills, as far south as the bend in the Blackfoot. The southern portion of this belt of hills is connected with Mount Putnam by a series of interpolated ridges, defining the water-shed between the Portneuf and Ross Fork drainages.

This belt is made up of Carboniferous limestones and siliceous deposits, Triassic sandstones, and Jurassic limestones and shales. In the southern portion of the belt these deposits occur in a rather shallow synclinal, defined on the east and west by the Carboniferous beds. But in the middle and northern portions these strata are complicated by displacements and foldings to such an extent as to render their study an exceedingly difficult undertaking. Here the geologist encounters the most conflicting manifestations of disturbance in the constant variation of dip and strike exhibited by the beds, and which, even in short distances, change from moderate inclination in one direction to vertical and inverted position; while the strike exhibits in the flexures of the strata all those irregularities which may be attributable to violent upheaval. None of the later members of the Cretaceous were identified in this region; but in the low border hills to the north of Fort Hall occur extensive deposits of yellowish and light-red sandstone, which may prove to belong to the earliest epoch of this period, though no certain evidence on this point was gained, more than that on the slopes outlying Higham's Peak on the west these beds overlie Jurassic limestones.

To the southeast, in the region of the southern bend of the Blackfoot River, to the west, but somewhat isolated from the above range of hills, in low isolated hills, and apparently also making up the bulk of low ridges intervening between the Blackfoot and a shallow basin next east of Lyncoln Valley, an extensive deposit of light-colored calcareous material was found, indurated layers of which contain great numbers of molds of gasteropods, identical with those occurring in similar deposits in the region of the debouchure of Bear River, and which have been referred to fresh-water forms of the Pliocene. These beds dip 25° east of north, and are overlaid by trachyte, also inclining northeast at an angle of 15° to 20°. Station 30 was located on one of these volcanic-capped Tertiary buttes. To the west of these Tertiary hills occur the conglomeratic deposits, dipping from northerly east, and finally southeast 10° to 20°, whose components show it to have been formed subsequent to the eruption of the volcanics, although these coarse materials are included in a fine paste which may be of volcanic origin. In this place mention should not be omitted of the existence of a low anticlinal axis or fold in the volcanics which occupy the Blackfoot Valley. From all a hasty trip reveals, it seems certain that this region has been subjected to intense volcanic action in comparatively recent times.

The Blackfoot Mountains are mainly composed of Carboniferous strata, which occur in a well-defined monoclinal ridge, but which really forms the remnant of an anticlinal fold, the axis of which lies about the middle of the range, the strike bending in and out but always crossing the range obliquely; to the north the beds dip off to the southwest, and to the south inclining northeasterly. Blackfoot Peak is a high culminating point on a sort of spur to the northeast of the main range, beyond which occur areas or belts of variegated early Mesozoic deposits. In the southern portion of the range, on the southwest flank, a considerable thickness of brown arenaceous and limestone deposits comes to view from beneath the Carboniferous beds, where they are seen to form the axis of the anticlinal fold. These deposits contain a meager fauna, which appear to be referable to Silurian forms. The Carboniferous mainly represents the earlier period, whose epochs are indicated by similar paleontological peculiarities which distinguish the Lower Carboniferous formations in the Mississippi Basin, and which more extended research will doubtless reveal in this distant region. But one of the most interesting discoveries in this connection was the presence of fish-remains, representing several forms identical with or closely allied to Keokuk species of the genera *Cladodus*, *Petalodus*, *Anthiodus*, *Helodus*.

Between the Blackfoot Mountains and the Blackfoot River, and occupying the angle in the southern bend of the Blackfoot, an isolated area of hills exhibits a series of strata, including the Upper Carboniferous on the north to the Jurassic on the south. The middle portion of this section is much disturbed and the exposures unsatisfactory. The former beds incline steeply southward, while in the Jurassic ledges on the south a marked anticlinal fold is observed, the strata inclining to the north and south either side of the axis. Stations 12 and 13 were located on ridges on the north side of this fold. The beds in this group of hills have veered round so as to have nearly east and west strike.

To the southeast of the Blackfoot Mountains, from which they are separated by a wide basin-plain floored with basalt, rise a couple of low parallel ridges, lying between John Gray's Lake and the upper basin of the Blackfoot River. The northeastern flank of the eastern ridge shows red sandstones, probably Triassic beds, and similar deposits occur on the opposite flank of the western ridge. Their present condition is that of monoclinal ridges, the strata of which show northeasterly and southwesterly dips, respectively. The eastern ridge shows the basalt reclining high up on its southwest flank, resting on the Carboniferous limestone near the crest of a sag in the ridge. Both ridges are, however, principally composed of Carboniferous limestone and siliceous beds.

East of the Blackfoot Mountains, the first low mountain eminence encountered appears to be a bulging up of the volcanics, the basalts rising up on the flanks of the ridge, whose summit is composed of scoriaceous lava. To the southeast the basalt has been denuded, leaving several low buttes of this rock, which seems to be connected with the deposit which fills the broad valley separating this from the Blackfoot Mountains. (Station 4.) But to the northward, beneath the basalt, the nucleus of the ridge displays a series of soft gray sandstones and harder red, coarse sandstones, with variegated shales, underlaid by drab-gray limestone containing great numbers of a small gasteropod, and which is in turn underlaid by hard light-red sandstones. These beds incline southwesterly, and together they represent a great thickness of strata. The ridge on the north is capped by trachyte, which dips at a steep angle into the Snake plains. The upper sandstones contain obscure vegetable remains, from which circumstance their Cretaceous age may be in ferred. The limestones and sandstones are again exposed to view in a low anticlinal ridge next east, which was thrust up by a rhyolitic (?) dike, on which station 17 was established. The limestone is also here charged with the same little gasteropod, and underlies the sandstone, which latter shows obscure plant-remains. The dips at the latter locality are southwest and northeast.

To the southeast of the above locality, in the vicinity of Gray's Lake, obscure outcrops of reddish and gray sandstone may be seen in a cluster of low hills just to the south of the lake. These beds dip at moderate angles to the southwestward, and on the westernmost low ridge among the *débris* an obscure *Ammonites* was found preserved in a fragment of gray limestone. It is uncertain whether these beds should be referred to the Cretaceous or Jurassic; but the fossils obtained will doubtless readily establish their age. To the west these beds are doubtless suddenly and sharply folded, as the Carboniferous appear in the before-mentioned pair of ridges just west of Gray's Lake and but a few miles from the above-mentioned exposures with *Ammonites*.

The Caribou Range occupies by far the largest area of any range in this region, and in its geological aspects it is also the most varied. Along the northeastern border at intervals, or near the northern extremity and again between the lower and upper basins in the Snake Valley, the range is flanked by heavy deposits of quartzites which resemble the ancient quartzites in Mount Putnam. This is succeeded by the Carboniferous, consisting of limestones and hard quartzitic sandstones, in the upper portion of which occurs a horizon charged with a peculiar lamellibranch fauna, which strongly recalls the Permian. This latter probably represents the equivalent of the Permo-Carboniferous in this region. Next in order of superposition is a thickness of several hundred feet of "red-beds," which is in turn overlaid by the peculiar light drab, indurated, calcareous shales and limestones of the Jurassic. Along the western border of the range, to the north, occurs a heavy series of reddish and soft, gray sandstone, imbedded with variegated shales, which contain vestiges of a flora represented by obscure impressions of woody stems and dicotyledonous leaves, (between stations 19 and 20.) Higher in the mountain slope these deposits are overlaid by gray and drab limestones, which afford a few small ostreas and the pentagonal disks of crinoid columns. The former deposits can hardly be referred to a more ancient period than the Cretaceous, while the latter as probably belong to the Jurassic; the relative position of the beds indicating a fold which overturned or inverted the strata. These or very similar gray sandstones were met on the eastern flank of Mount Bainbridge, where they are followed above by dark shales, here much changed by contact with the intruded volcanics and the limestone cap of the mountain, which latter afforded traces of a little gasteropod, apparently similar to those occurring in before mentioned limestones found elsewhere in connection with these gray and reddish sandstones. The general strike of these strata is northwesterly and southeasterly, though subject to great variation even along the same line of exposure in crossing the series; while they are much folded, which greatly complicates their study, rendering accurate measurements impracticable in the hurried examinations made. There are three or four conspicuous folds, one of which is a sort of double fold, which at one point shows an abrupt flexure in the strata involved which may at other points have completely severed the bed, resulting in a fault. As already intimated, the region is further complicated by inverted beds, and in certain parts there are found the most contradictory dips, indicating a chaotic condition, the result of intense local disturbance. The vertical displacement is very great, and the amount of material which has been removed by erosion, and this, too, within a comparatively not remote date, is almost inconceivably great.

Allusion has already been made to the Mount Bainbridge volcanics, where these igneous products are so intruded in the limestones and shales as to present the appearance of regularly-bedded deposits. Associated with the eruptive rocks at this locality are auriferous lodes of some richness, which have given a fair supply of gold to the placers, though as yet little has been done toward developing the lodes themselves. It is presumable that all the placer diggings in the Caribou district received their gold from the lodes intersecting Mount Bainbridge. The intrusion of this great mass of eruptive rock does not appear to have greatly disturbed the sedimentaries, since the southwesterly inclinations observed in ascending the eastern slope of the mountain are continued down the opposite slope and as far as Gray's Lake Basin, the only change of note being the gradual flattening of the angle of inclination as we recede from the range westerly. While the Carboniferous deposits appear to be mainly, if not wholly, restricted to the northeastern border of the range, the Jura-Trias composes the bulk of the central portion, with belts of the variegated shales and sandstones of later date in the southwest; all of which share equally in the effects of upheaval, which has folded and warped these deposits in a remarkable manner.

There remains to be noticed the occurrence, in the upper basin of the Snake Valley, extending up to the debouchure of the grand cañon, of a peculiar deposit of variegated clays and partially indurated sands, which fill this part of the valley. These beds are extensively exposed in the right bank of the Snake River below the confluence of Salt River, and also may be seen in the opposite side, that along which the party traveled, and where their tilted edges are planed off to various terrace-levels, marking the work of the river erosion, and the whole overlaid by the coarse materials out of which the more modern terraces were formed. These beds incline quite uniformly obliquely up stream, or in an easterly direction, at angles of 35° to 40°. Their tilting it is difficult to account for, since they are unconformable to the older formations in either the east or west side ranges bordering the Snake Valley; and yet it seems almost certain that they owe their present position to disturbances lying to the westward, in which case it may enable the determination with a good degree of accuracy the precise age of at least (if there be more than one such) the latest upheavals which have taken place in the Caribou Range. I take it these valley deposits are of late origin, probably Tertiary lacustrine beds.

Below the mouth of Salt River occur extensive deposits of calcareous tufa, jutting out into the valley in low platforms, in the neighborhood of which saline springs are flowing feebly to-day. Again, in the little basin-valley east of Lyncoln Valley, quite extensive calcareous deposits floor the valley, in the midst of which are vestiges of the now extinct springs from whose flow this material was precipitated. The little streams which rise in the Blackfoot Mountains also contain much lime, which is deposited on stones and sticks in the beaver-dams in their lower courses. But none of these accumulations are comparable to the enormous spring-deposits met with in the northeastern foot of the Wind River Mountains, in the upper portion of the Wind River Valley, which were hastily examined later in the season.

Reference has been made in the foregoing pages to the evidence bearing on the age of some of the disturbances which have taken place in the Caribou Range, and which would appear to have taken place at a comparatively modern date, or subsequent to the deposition of the Tertiary lake-beds. In the valley of the Blackfoot are found a set of loose sand and conglomerate deposits, which are apparently of later date than the period of basaltic effusions, and which were tilted by forces lying to the westward, the beds dipping toward the Blackfoot Range. Hence, it is reasonable to infer that these deposits, together with the Pliocene shell-beds in the same quarter, were tilted at the time of the disturbances which folded and complicated the strata in the belt of hills lying between the Blackfoot and Lyncoln Valley, and which does not appear to have affected the Blackfoot Mountains, whose elevation is probably referable to an earlier date, or late Mesozoic time.

In conclusion, it may not be out of place to mention the beautiful scenery of this region, its grassy hills and plains, and its many tracts of arable land adjacent to the numerous little streams of pure water which drain the region. For the purposes of stock-growing the country offers many inducements. Save in the plains bordering the Snake River, where excellent crops of small grain and vegetables are grown, we have not the aid of experiment to guide to positive information respecting the agricultural capability of the tracts of fertile valley-soil everywhere found, and which can be easily irrigated. But even in the high basin, or mountain valley, in the Caribou district, oats and the hardier vegetables are grown. There is a scarcity of wood, and the largest forest tracts are generally in the most inaccessible localities.

That portion of the district next visited comprises ground which was partially explored by the expedition of 1872. Hence, during the limited time the present party spent in this region, it was principally the geologist's aim to visit those quarters which had not previously been examined. This region embraces all that portion of the district lying in the great southern bend of the Snake River, extending northward to the northern boundary, and in area more than a third greater than the previously noticed region lying to the southwest. The whole northern portion is occupied by the plains of the Snake Basin, which in the west and northwest are interrupted by a cluster of low volcanic cones, surrounded by sand-hills. On the east the plains rise into the broad ridge which slopes off from the northern end of the Teton Range, and which merges into the low, densely-wooded water-shed separating the Henry's Fork drainage on the west from the upper waters of the main Snake River on the east. The entire extent of the plains region, including the before-mentioned low water-shed, is immediately underlaid by volcanic rocks. A vast sheet of lava-basalt is spread over the extensive lower levels of the plain. In the sloping upland border region to the south, these basaltic rocks are succeeded by a laminated variety, associated with trachytic material, which gently rise upon the flanks of the highlands to the southward, precisely in the manner observed in connection with the volcanics in the southwestern portion of the district. Pierre's Basin, which lies between the Teton Range and the northern portion of the Snake River or Pierre Mountains, forms a sort of estuary, opening out north into the Snake plains, up which the laminated and trachytic volcanics extend—on the east side as far as the mouth of Teton Pass, and on the west side about half the distance toward the head of the basin. Formerly, doubtless, the entire area of this basin was floored with these rocks; but to-day they are only observed in isolated patches, reclining on the foot of the surrounding mountains, while in the valley they are covered by Post-Tertiary deposits of water-worn gravel and bowlders and the silted washings from the surrounding slopes. To the north of West Teton Creek, however, the volcanics constitute a prominent feature in both the basin plain and in the foot of the mountains. They are here seen to rise up on the flank of the range to an elevation of 2,000 feet above the basin, forming a wide, heavily-timbered foreland, lying between the mountains and the plain. In this border region the streams are deeply cañoned.

In Pierre's Basin, as also in the bottoms along Henry's Fork and its tributaries, accumulations of water-worn drift materials are prevalent, mainly consisting of quartzite bowlders, with more rarely limestone, granitic, and volcanic bowlders; the three former varieties derived from ledges in the Teton Range and the mountains to the south and west. These drift materials were also occasionally observed in the uplands, where they are weathered out in the slopes immediately bordering the cañoned courses of the streams; showing their general distribution over the entire area of the volcanics, as well upon the sloping upland as in the river-bottoms. Indeed, on some of the high crests in the northern part of the Teton Range, quartzite and gneissose bowlders are sparsely present in situations where their presence cannot be accounted for satisfactorily without the intervention of glacial transporting agencies.

A march of eight days' duration from Fort Hall brought the party to the Teton Mountains, near the northern end of which, on the west side, the first ascent was made. This range, in its present condition, may be described as a gigantic monoclinal ridge, with a metamorphic and granitic nucleus which forms a lofty, exceedingly rugged, jagged crest, extending in a north and south direction three-fourths the length of the range, and which culminates in Mount Hayden. The eastern face is suddenly broken down in precipitous walls and steep slopes, which descend into Jackson's Basin. The western slope throughout its extent is covered by the sedimentaries, dipping to the westward at comparatively moderate angle of inclination. About midway between West Teton Cañon and the northern terminus of the range, the continuity of this sedimentary foreland is suddenly interrupted by a rugged spur of Archæan rocks, thrown off from the main range to the east, and which separates the sedimentary area into two portions. The northwest terminus of this spur reaches quite across the belt of lofty summits outlying on the west the Archæan belt, the volcanic ledges lapping up on its foot, and beneath which the sedimentaries are concealed. The structural features of the range, so far as relates to the sedimentaries, are comparatively simple. To the north, where the volcanics reach high up on the western flank, in one of the cañoned sources of the North Fork of Pierre's River, the lowest ledges *in situ* consist of a considerable thickness of thin-bedded drab limestone, which I take to be Quebec. Above this occurs a heavy ledge of buff magnesian limestone, showing a thickness of 100 feet or more, and which contains obscure corals resembling Niagara forms: Above the latter, to the summit of the high ridge on which station 32 was made, occurs a thickness of 1,500 feet of Carboniferous deposits. At this point these deposits show a gentle inclination northwesterly; but to the north, at the base of the same mountain, the northeasterly dip of these strata indicates a synclinal depression at this point. Beyond, in the same directiod, and near the terminus of the range, the strata are steeply tilted or upturned, with sharp westerly dips, as though the result of the upheaval of the Archæan ridge which lies just to the east. From such observations as Mr. St. John was able to make, it appears that the sedimentaries which may once have folded continuously round the north extremity of the range, were extensively denuded prior to the eruption of the volcanics, which overlap alike the sedimentary outlying deposits and the Archæan areas, wherever the latter reach the western and northern borders of the range. To the south of the above-mentioned Archæan spur, the same series of sedimentaries recur, and which extend high up on the more elevated portions of the range, sloping thence to the westward in the direction of Pierre's Basin. But to the south of the West Teton Creek Cañon, a series of deep red arenaceous shales and sandstones are superimposed on the Carboniferous, the capping of intensely hard siliceous rock or quartzite forming an effectual protection to the foreland, which here sweeps down in long, comparatively regular slopes into the valley. These latter deposits here show a thickness of 300 to 500 feet. On the lower slopes of the foreland, apparently overlying these red-beds, obscure traces of drab limestone, not unlike Jurassic deposits found elsewhere in the district, occur. Though no fossils were observed in these beds, it will at once occur to you that they are probably Triassic. These red-beds form a conspicuous feature in the magnificent escarpments thence southward nearly to Teton Pass Creek, where they have been denuded, the Carboniferous beds again appearing in the base of the mountains. In passing southward along the west flank of the range, the inclination of the sedimentaries is observed to gradually change from a north of west to west and southwest direction. In the vicinity of Teton Pass, to the southwest, are evidences of unusual disturbance, the Carboniferous beds being suddenly upturned, forming what appears to be a short, sharp fold, with steep easterly dip and more gentle westerly inclination. The pass itself is eroded out of the "red-beds" and siliceous upper deposits of the Carboniferous. While obscure exposures of brownish-gray limestone containing a small ostrea-like shells and soft gray sandstone indicate the presence of the Jurassic, and probably the Cretaceous, which seem to occupy a synclinal depression whose axis deviates more to the east of south from the prevalent strike of the sedimentaries in the Teton Range, and in this respect corresponding intimately with the folds afterward observed in the mountains on the west side of Pierre's Basin.

The Teton Range terminates rather suddenly in lofty peaks sculptured out of the sedimentaries, to the south and southwest of which a much lower but very broken mountain tract extends to the grand cañon of the Snake River. This tract is crossed by broad belts of "Red Beds," drab and buff beds, corresponding to the Triassic, Jurassic, and, possibly, Cretaceous, and which are limited in the distance by rugged crests composed of gray ledges, which may prove to be the Carboniferous basin bounding the Snake River. The high peaks which rise immediately to the north of Teton Pass summit are made up of Carboniferous strata, dipping a little north of west at angles of 10° to 45°; to the west, however, the same deposits incline at much steeper angle, as noticeable in the acclivities on the north side of Teton Pass Creek. These ledges sweep up over the summit of the range, forming lofty ridges which break down abruptly on the east in a succession of escarpments and steep *débris* covered slopes. East of the summit of Teton Pass, in descending to Jackson's Basin, the granitic nucleus cannot lie far beneath the bed of the cañon, since the short northern tributary cañons have brought down much granitic *débris;* but below this still, in a bulky outlying ridge at the debouchure of East Pass Creek, the Carboniferous again appears, also dipping north of west at a moderate angle. Farther north, in these east-facing sedimentary escarpments, where the whole series of Palleozoics occurring in this region is revealed in magnificent exposures, a fold or undulation in the strata is observed by which the Carboniferous beds are carried down along the east slope to a level far below the lofty summits which the beds crown along the crest of the range; a similar fold would explain the occurrence of the low-lying exposures in the debouchure of East Pass Creek, above noticed. Beneath the sedimentaries at this point the Archæan rocks are exposed, and which descend in steep, rugged slopes to the level of the valley. To the north still, the Archæan nucleus rises higher and higher, carrying up with it the sedimentaries, which gradually disappear, one formation after another, until only Quebec is seen, forming a coping of dark limestone to some of the high ridges south of Mount Hayden, and where they are finally crowded back, occupying subordinate ridges west of the main crest. The east face of the range from the vicinity of the Tetons to its northern extremity shows only the Archæan rocks. It is very probable that the sedimentaries were profoundly faulted along the east side of the range, along which side, it would appear, the greatest force was expended in the upheaval. But toward the extremities of the range, where these forces were less violent, the sedimentaries may have been merely crumpled or folded in the manner apparent in the southern extremity of the range.

Subsequent erosion has greatly changed the surface contour, and obscured many details, but the general features are still manifest.

A brief visit to the Pierre Mountains, on the west side of Pierre's Basin, afforded opportunity for the study of the structural features of the eastern half of the range. This range intersects the Teton Range at a sharp angle, its general direction being northwest and southeast, and forming an exceedingly broken mountainous belt between Pierre's Basin and the Snake River. In its geological structure it is intimately related to the Caribou Range on the opposite, west, side of the Snake River. The range exhibits a series of folds, whose axes extend in a general direction northwesterly and southeasterly, and in which are exposed typical exhibitions of the Carboniferous, Triassic, and Jurassic, and probably the Cretaceous formations. Along the eastern border, toward the northern extremity of the range, in a section much complicated and broken up by the forces which folded the beds, occur a series of gray sandstones and shales which closely resemble deposits found in the Caribou Range, which have been referred to the Cretaceous. These beds appear in low ridges, upon which lap the volcanics in long, gentle ascents from the cañon-scored plain of Pierre's River to the northeast and north. To the southwest a wide belt of Carboniferous is met, showing the entire thickness of the formation, which is made up of limestones and heavy siliceous deposits. On the southwest side of the anticlinal in which these limestones are exposed, a heavy series of deep red gritty shales and sandstones, reaching a thickness of 1,500 feet or more, occur, which represent the Triassic. Succeeding the latter, occur a set of beds made up of limestones and drab indurated calcareous layers, with Jurassic fossils, representing a thickness of a thousand feet or more. These are followed by a series of heavy deposits of hard sandstones and variegated clays, resting upon a heavy ledge of conglomerate near the base. To the southwest, occupying the intervening belt lying in the heart of the range, a labyrinth of deep cañons and sharp ridges, similar deposits are here and there indicated, bounded in the distance by the more uniform and even loftier mountain wall along the northeast margin of the Snake Valley, which appears to consist of Carboniferous strata. These several folds, so far as I was able to determine, are pretty constant for long distances. Although the middle part of the range has been much eroded, so as to cause the Carboniferous to flank the mountains between Horse Creek and the head of Pierre's Basin, the outer belt of Cretaceous near the northern end of the range probably belongs to the same fold which lies just to the southwest of Teton Pass; while the inner folds above alluded to correspond to those observed in the southeastern half of the range to the southwest of Teton Pass. The condition of the sedimentaries in the interval embraced to-day in Pierre's Basin, of course remains conjectural, these rocks being hidden from observation beneath the volcanic sheet which at a later date flooded the valley. From the relative age of the folding of the strata which make up this range, compared with other neighboring ranges, it seems probable that the date of its upheaval is referable to a time antecedent to that during which the disturbances took place which resulted in the folding of the Caribou Range, and probably subsequent to the upheaval of the Teton Range. This latter forms a unique as it is one of the grandest ranges in the West. In many particulars it bears a more striking resemblance to the Wind River Mountains than it does to the low but much more complicated ranges which it dominates.

That which forcibly strikes the observer on entering Jackson's Basin, which lies at the east base of the Teton Range, is the vast accumulation of drift materials with which the valley is filled. Along the west side of the basin extensive morainic accumulations in irregular, wooded ridges, outlying the debouchures of the cañons which penetrate the range; while the stream itself, in various stages, has fashioned these materials into beautiful terrace formations. Scarcely anything could offer greater contrast than that presented by the mountain environments of this basin. The Teton Range forms a rugged, almost precipitous barrier on the west, which rises 4,000 to 7,000 feet above the valley. To the east the country rises in gentle, wooded ascents, culminating in clusters of low mountain elevations which are connected by high mountain plateaus with the continental water-shed. To the southeast of the Teton range, and running up into the angle formed by the confluence of the Snake and Grosventre Rivers, lies a rather lofty and very rugged range of mountains which occupies a considerable area between the Grosventre and the headwaters of Green River, and which forms a sort of transverse belt connecting the Teton Range with the Wind River Mountains to the east. This range is known as the Grosventre or Wyoming Mountains. The geologist's examinations were confined to the western portion of the range. Here he meets with an Archæan (gneissic) nucleus, which in places penetrates through the heavy mantle of sedimentaries in sharp peaks which but for the presence of the colossal Tetons would elicit admiration for their real grandeur and perfect mountain contour. In many respects the range presents marked resemblance to the Teton Range, and probably its relationship to the Wind River Mountains is even more intimate. The sedimentaries have been uplifted bodily upon portions of the range, though they exhibit evidences of great disturbance and of the unequal distribution of the elevatory forces, which have in places sharply folded the strata. One of these Archæan peaks sends down a sharp spur to the westward, which terminates rather abruptly in the valley at a point about opposite the Lower Grosventre buttes. Between the latter and the foot of the spur, a little stream has excavated a widish valley, in the west side of which, in a line of bluffs, dark weathered ledges appear, gently dipping westerly, and which are probably Quebec. In the northern butte, Professor Bradley mentions having observed volcanic ledges ("porphyritic breccias,") and to the south limestones in horizontal position, which are referred to the Carboniferous. The volcanic capping gradually rises to the southeast, and finally disappears. A similar remnant occurs on Elkhorn Creek, near the edge of the basin, where it rests upon Tertiary deposits. To the north of the above-mentioned spur, in the foot of the foreland, outcrop ledges of thin-bedded drab limestone, dipping northwesterly, which are undistinguishable from the Quebec limestones occurring in the Teton Range. Ascending this foreland, eastward, the same limestones are exposed at frequent intervals, showing the same dip, and in places overlaid by remnants of the buff magnesian limestone referred to the Niagara. These deposits finally give way to densely wooded *débris* slopes, which reach up to the Archæan peak of station 44, like gigantic moraines. From this point an excellent opportunity is had for the study of the rugged and almost inaccessible mountain highlands which make up the broad northern summit of the Grosventre Range. It is a region of lofty ridges and profound amphitheaters, whose precipitous walls exhibit the complete sedimentary series from quartzites to the Carboniferous, and off to the east heavy deposits of the Triassic "red beds" cap high ridges. The region strongly recalls the Teton Range, but the sedimentaries are much more disturbed, and, as a consequence, this highland is more uneven than that along the west summit of the latter range. A few miles to the northward, the foreland which rises into station 46 from the debouchure of the Grosventre, exhibits the Carboniferous dipping northerly, and which extends to the summit of this lofty peak. These beds pass beneath the Triassic, which appears in line of vermillion bluffs along the north side of Grosventre Cañon, beyond which the hills gradually rise into a high conical peak which forms the culminating point of the highlands between the Grosventre and Buffalo Fork, and which is known as Mount Leidy. Overlying the Triassic red beds, a broad belt shows light drab deposits which also dip northerly, and which hold the position and have the appearance of the Jurassic, though no fossils were observed in the limestones, which in part make up these latter deposits, by which their age could be determined. The space intervening between the latter deposits and Mount Leidy is more broken, and apparently consists of an extensive accumulation of softer deposits. The lower portion of these are found to consist of light and yellowish soft sandstones and clays, capped by light-brownish beds, which are finely displayed in Mount Leidy, whose steep slopes the elements have beautifully sculptured. In the northern foot of Mount Leidy, the lower or middle beds of this series exhibit an exposure of one or two hundred feet in cañon-bluffs of Elkhorn Creek, in the base of which a thin bed of rotten lignite was found. He failed to detect any traces of organic remains in these beds, and am, in consequence, unable to refer them to their place in geological time, though I believe they belong to the Tertiary. The northerly inclination of these beds at a gentle angle continues across the low upland to the Buffalo Fork, and in the hills which rise on the north of this stream similar beds of clays and buff sandstone outcrop, where they attain elevation of above 2,000 feet above the valley. These hills are capped by bed of partially cemented bowlders and pebbles, the degradation of which has strewn the slopes with drift *débris*. The above-mentioned Tertiary deposits were met in the gradually-ascending upland to the east as high up as the debouchure of the Buffalo Fork, though they were not observed to extend up on the mountain sides in this quarter.

From the Buffalo Fork the route led up Black Rock Creek, through the To-owo-tu Pass, across the continental divide into the Wind River Valley. Just within the western entrance to the pass, on the north side, a group of high mountains occupies the interval between Black Rock Creek and Buffalo Fork, of which Buffalo Fork Peak forms the culmination. The bases of these mountains, together with the corresponding heights on the opposite side of Buffalo Fork, and which together form the gateway to the upper mountain valley of this stream, are composed of Archæan (gneissose) rocks, which constitute a thousand or more feet of the lower portion of the cañon-walls. Upon these rests a thickness of one hundred feet or more of quartzite, and upon the latter a heavy ledge of the lower Quebec limestone occurs, forming the summit of Buffalo Fork Peak. This mountain is connected with the lower peak, station 49, to the southwest, by a long spur, in which this limestone forms the coping and dips in the same direction. It is overlaid by the thin-bedded upper ledge, with a considerable thickness of intervening clays and indurated fine-grit layers, in all of which Trilobites and other Silurian fossils were found. These beds are in turn overlaid, without apparent unconformability, by several hundred feet of Carboniferous, which latter crowns the summit of station 49. The southern slopes of these mountains steeply descend over heavy ledges of limestone and grayish buff and reddish hard sandstone into the valley of Black Rock Creek, where the deep red sandy shales and sandstone of the Triassic outcrop, and the presence of which in the adjacent slopes is plainly hinted by the rank herbaceous vegetation its soil supports. The same deposits are also seen to the east or southeast, reclining on the southeasterly declivities of these mountains, in the gap which separates them from the volcanic escarpments of the main water-shed. This group of mountains appears to owe its origin to a local bulging of the crest, since to the north the sedimentaries which it bears on its crest are seen to dip off in that direction, as they do in the opposite direction on their western and southern flanks, overlooking the lower valley of the Buffalo Fork and the upper course of Black Rock Creek in the approach to To-owo-tu Pass. The latter valley, like the Teton Pass, (and for that matter, so many of the passes in the mountains of this region,) is excavated in the Triassic red-beds. To the southwest of the Black Rock indications of the presence of the Jurassic are obscurely revealed here and there, but soon concealed in the long, wooded slopes, which are continuous with the Tertiary ridges of the Mount Leidy region.

In the valley of Black Rock Creek are encountered heavy masses of volcanics consisting largely of a sort of conglomerate breccia. These continue to the summit of To-owo-tu Pass, where they are seen in intimate association with some of the most remarkable volcanic accumulations. The latter rise into lofty horizontally-bedded mountains whose sides are sculptured in colossal architectural forms, and which form a grand portal to the pass across the continental divide. The heights command Jackson's Valley and the Teton to the westward, while to the eastward lies the low country of the Wind River Valley, diversified by the peculiar variegated formations which occupy a great basin bounded on the north by the continuation of the volcanic cliffs. These latter offer on close examination the most varied appearance, being made up of volcanic ash, sands, breccias, and conglomerate, which are partly of aqueous origin, as shown by their bedded condition. These strata are practically horizontal, although they incline slightly in various directions, but appear not to have been affected by disturbances such as elevated the Buffalo Fork Mountains, and hence the more recent date of their formation is inferred.

To the east, north, and northwest, these deposits are spread over an immense area of elevated mountain country, themselves constituting some of the highest elevations in the region. Their *débris* effectually conceals the older rocks in the To-owo-tu Pass, to the south of which the same great escarpments are continued for a short distance, when they give way to lower levels of long, wooded mountain summits. In the latter appear heavy exposures of dark, compact, and scoriaceous lavas, with trachytic domes. These extend along the summit of the water-shed several miles in a southerly direction, and may reach to the near vicinity of Union Pass.

Descending into the Wind River Valley, a few miles below the summit of the pass, the bluff banks along the stream show a hundred feet or so of cream-colored and buff sandstone and gritty clays. These deposits gradually increase in vertical exposure as we descend the valley, the beds gently inclining in the same direction, or southeasterly. At a point where the stream opens out into the intervale-bordered valley these beds are seen to be overlaid by a series of variegated, red, greenish, and buff or ash colored clays, and indurated arenaceous beds, which make up a thickness of several hundred feet in a rather high plateau or terrace outlying the high volcanic ridges which hem the basin on the north. These deposits continue down the valley several miles farther, lower beds coming to view as we descend. Above De Noir Creek, in a low bluff on the north side of Wind River, a thin seam of lignite occurs in connection with bluish-drab and chocolate-colored clays and rusty, soft sandstone. In the neighborhood of Warm Water Creek we first met the older sedimentaries, which appear in a mass of reddish and light colored sandstones reclining on the foot of the Wind River Mountains, dipping 20° to 30° northeasterly. The sandstones are underlaid by older formations, which rise successively higher and higher upon the northeastern face of the range.

In the same neighborhood, on the northeast side of the river, a series of beautifully exposed deposits, consisting of variegated, light-red, and drab clays, and bands of ferruginous sandstone, capped by yellowish sandstone, appear, and which seem to underlie conformably the before-mentioned horizontal deposits. These variegated beds continue thence far down the valley; but above Crow Heart Butte they are crowded inland, the terraces which bound the stream showing buff sandstones, and which, together with brownish clays, make up the rock exposed in the above-named butte. In the vicinity of the confluence of North Fork the variegated beds exhibit their greatest development, as shown at any one point observed. Here they are seen to rest upon brown clays, recalling the clays interbedded with the sandstones in Crow Heart Butte, and all of which rest unconformably upon the more steeply-inclined Jurassic limestone and Triassic sandstone, which here form a wide belt of exposures in the foot of the mountain. The variegated beds are also slightly inclined northeasterly.

Below Bull Creek we soon enter a region where the Mesozoics extend several miles out into the plains, which here intervene between the river and the foot of the mountains; a section where they exhibit much displacement, which contrasts with the grand simplicity which uniformly characterizes the position of the Mesozoic and Paleozoic formations in the great foreland slopes of the range between the Warm Water and Little Wind Rivers.

Thence, on their return, the party passed through Mr. Chittenden's district, which was visited by Dr. Endlich.

The necessity of a careful examination of the various geological formations in the field, and a review by a practical paleontologist of the various districts that have from year to year been surveyed by the different geologists of this and other surveys, has been long felt. Such a work, indeed, was imperatively necessary before a consistent and comprehensive classification of the formations could be established. This duty was assigned to Dr. C. A. White, the palæontologist of this Survey, and he took the field at the beginning of the past season and continued his labors until its close. The special duty with which he was charged was to pursue such lines of travel as would enable him to make critical examination of the geological formations in succession as they are exposed to view on both sides of the Rocky Mountain chain, and also on both sides of the Uintah chain; to collect and study the fossils of these formations in such detail as to settle, as far as possible, the questions of the natural and proper vertical limits of the formations, their geographical range, their correlation with each other, and to define the paleontological characteristics of each.

He has pursued his researches with such success during the past season as to demonstrate the necessity of continuing this class of investigations by various lines of travel across what is generally known as the great Rocky Mountain region, especially those portions of it that have been surveyed, as well as those in which surveys are in progress.

Among other important results, he has shown the identity of the lignitic series of strata east of the Rocky Mountains in Colorado with the Fort-Union group of the Upper Missouri River, and also its identity with the great Laramie group of the Green River Basin and other portions of the region west of the Rocky Mountains. He also finds the planes of demarkation between any of the Mesozoic and Cenozoic groups, from the Dakota to the Bridger inclusive, to be either very obscure or indefinable; showing that whatever catastrophal or secular changes took place elsewhere during all that time, sedimentation was probably continuous in what is now that part of the continent from the earliest to the latest of the epochs just named. Other results and further details of the season's work will appear in the following paragraphs.

The general course of travel pursued by Dr. White during the season was as follows, not including the numerous detours, meanderings, and side trips which the work necessitated: Outfitting at Cheyenne, he journeyed southward, traversing in various directions a portion of the great plains which lie immediately adjacent to the eastern base of the Rocky Mountains in Colorado. The most easterly point thus reached was some sixty miles east of the base of the mountains and the most southerly point about twenty-five miles south of Denver. Returning to Denver to renew his outfit, he crossed the Rocky Mountains by way of Boulder Pass, through Middle Park. After making certain comparative examinations of the Mesozoic and Cenozoic formations in Middle Park he proceeded westward to the headwaters of the Yampa River, following that stream down to the western foot-hills of the Park Range of mountains.

Here resuming his comparative examinations of the Mesozoic and Cenozoic strata, he passed down the valley of the Yampa as far as Yampa Mountain, one of those peculiar and remarkable up-thrusts of Paleozoic rocks through Mesozoic strata. In all this area, as well as that between the Yampa and White Rivers, the Laramie group reaches a very great and characteristic development, and it received careful investigation, yielding some of the most important results of the season's work. Crossing the ground between the two rivers named to White River Indian agency, thence down White River Valley about one hundred miles; thence to Green River, crossing it at the southern base of the Uintah Mountains, making many detours on the way, he reviewed the geology of the region which he had surveyed during the previous season. This review brought out not only the important paleontological facts before referred to, but it also added materially to the elucidation of the geological structure of the region which lies between the eastern end of the Uintah Mountain Range on the west and the Park Range on the east.

Beyond Green River he pursued his travels westward, studying the Mesozoic and Cenozoic strata that flank the Uintah Range upon its south side, and making comparisons of both their lithological and paleontological characteristics.

In this way he traversed the whole length of the Uintah Range, crossing at its junction with the Wasatch Range over into the valley of Great Salt Lake. Recrossing the Wasatch to the north side of the Uintah Range he continued his examinations of the Cretaceous and Tertiary strata into and entirely across the great Green River Basin, leaving the field at the close of the season at Rawlins Station, on the Union Pacific Railroad.

A general statement of the results of the season's work has been given in a previous paragraph, but the following additional summary will make the statement somewhat clearer, being made after the route of the season's travel has been indicated. The formations of later Mesozoic and earlier Cenozoic ages, especially those to which Dr. White, in former publications, has applied the provisional designation of "Post-Cretaceous," have received particular attention. The extensive explorations of Dr. Hayden in former years, and the paleontological investigations of the late Mr. Meek, pointed strongly to the equivalency of the Fort Union beds of the Upper Missouri River with the lignitic formation as it exists along the base of the Rocky Mountains in Colorado, and also to the equivalency of the latter with the Bitter Creek series west of the Rocky Mountains. The investigations of this year have fully confirmed these views by the discovery not merely of one or two doubtful species common to the strata of each of these regions, but by an identical molluscan fauna ranging through the whole series in each of the regions named.

This shows that the strata just referred to all belong to one well-marked period of geological time, to the strata of which Mr. King has applied the name of "Laramie group," (Point of Rocks group of Powell.) His investigations also show that the strata, which in former reports by himself and Professor Powell have been referred to the base of the Wasatch group, also belong to the Laramie group, and not to the Wasatch. He has reached this later conclusion not merely because there is a similarity of type in the fossils obtained from the various strata of the Laramie group with those that were before in question, but by the specific identity of many fossils that range from the base of the Laramie group up into and through the strata that were formerly referred to the base of the Wasatch. Furthermore, some of these species are found in the Laramie strata on both sides of the Rocky Mountains. Thus the vertical range of some of these species is no less than three thousand feet, and their present known geographical range more than a thousand miles.

Besides the recognition of the unity of the widely-distributed members of the formation of this great geological period, bounded by those of undoubted Cretaceous age below and those of equally undoubted Tertiary age above, his further observations have left comparatively little doubt that the "Lake Beds" of Dr. Hayden, as seen in Middle Park, the "Brown's Park group" of Professor Powell, and the "Uintah group" of Mr. King, all belong to one and the same epoch, later than and distinctly separte from the Bridger group.

In that portion of the region which lies adjacent to the southern base of the Uintah Mountain Range, and which is traversed by Lake Fork and the Du Chesne River, not only the Uintah group, but both the Green River and Bridger groups also, are well developed, each possessing all its peculiar and usual characteristics as seen at the typical localities in the great Green River Basin, north of the Unitah Mountains. This, added to the known existence of Bridger strata in White River Valley, and the extensive area occupied by the Green River group between White and Grand Rivers, has added very largely to our knowledge of the southward extension of those formations.

In all the comparative examinations of the formations or groups of strata that have just been indicated, he has paid especial attention to their boundaries,or planes of demarkation, crossig and recrossing them wherever opportunity offered, noting carefully every change of both lithological and paleontological characters. While he has been able to recognize with satisfactory clearness the three principal groups of Cretaceous strata, namely, the Dakota, Colorado, and Fox Hills, on both sides of the Rocky and Uintah Mountains, respectively, they evidently constitute an unbroken series, so far as their origin by continuous sedimentation is concerned. While each of the groups possesses its own peculiar paleontological characteristics, it is also true that certain species pass beyond the recognized boundaries of each within the series.

The stratigraphical plane of demarkation between the Fox Hills, the uppermost of the undoubted Cretaceous groups, and the Laramie group, the so-called Post Cretaceous, is equally obscure; but the two groups are paleontologically very distinct, inasmuch as the former is of marine origin, while the latter, so far as is now known, contains only brackish-water and fresh-water invertebrate forms. He reports a similar obscurity, or absence of a stratigraphical plane of demarkation, between the Laramie and Wasatch groups, although it is there that the final change from brackish to entirely fresh water took place over that great region. Furthermore, he finds that while the three principal groups of the fresh-water Tertiary series west of the Rocky Mountains, namely, the Wasatch, Green River, and Bridger groups, have each peculiar characteristics, and are recognizable with satisfactory distinctness as general divisions, they really constitute a continuous series of strata, not separated by sharply-defined planes of demarkation, either stratigraphical or paleontological.

During the progress of the field-work, as above indicated, large and very valuable collections of fossils have been made, all of which will constitute standards of reference in the future progress of the work, and quite a large number of the species are new to science. These are now being investigated, and will be published in the usual paleontological reports of the survey.

Messrs. S. H. Scudder, of Cambridge, and F. C. Bowditch, of Boston spent two months in Colorado, Wyoming, and Utah, in explorations for fossil insects, and in collecting recent Coleoptera and Orthoptera, especially in the higher regions. They made large collections of recent insects at different points along the railways from Pueblo to Cheyenne and from Cheyenne to Salt Lake, as well as at Lakin, Kans., Garland, and Georgetown, Colo., and in various parts of the South Park and surrounding region.

For want of time, they were obliged to forego an anticipated trip to White River, to explore the beds of fossil insects known to exist there. Ten days were spent at Green River and vicinity in examining the Tertiary strata for fossil insects, with but poor results; the Tertiary beds of the South Park yielded but a single determinable insect, but near Florissant the Tertiary basin, described by Mr. Peale in one of the annual reports of the survey, was found to be exceedingly rich in insects and plants.

In company with Rev. Mr. Lakes, of Golden, Mr. Scudder spent several days in a careful survey of this basin and estimates the insect-bearing shales to have an extent at least fifty times as great as those of the famous locality at Œningen in Southern Bavaria. From six to seven thousand insects and two or three thousand plants have already been received from Florissant, and as many more will be received before the close of the year.

Mr. Scudder was also able to make arrangements in person with parties who have found a new and very interesting locality of Tertiary strata in Wyoming, to send him all the specimens they work out, and he confidently anticipates receiving several thousand insects from them in the course of the coming winter. The specimens from this locality are remarkable for their beauty. There is, therefore, every reason to believe the Tertiary strata of the Rocky Mountain region are richer in remains of fossil insects than any other country in the world, and that within a few months the material at hand for the elaboration of the work on fossil insects, which Mr. Scudder has in preparation for the survey, will be much larger than was ever before subject to the investigation of a single naturalist.

Prof. Joseph Leidy, the eminent comparative anatomist and microscopist, made his second visit to the West the past season, under the auspices of the survey. He made a careful exploration of the country about Fort Bridger, Uintah Mountains, and the Salt Lake Basin, in search of rhizopods. He has been engaged for a long time on a memoir on this subject, which will eventually form one of the series of the quarto Reports of the Survey.

The rhizopods are the lowest and simplest forms of animals, mostly minute, and requiring high power of the microscope to distinguish their structure. While most of them construct shells of great beauty and variety, their soft part consists of a jelly-like substance. This the animal has the power of extending in threads or finger-like processes, which are used as organs of commotion and prehension, often branching. From the appearance of their temporary organs, resembling roots, the class of animals has received its name of rhizopoda, meaning literally root-footed.

In compensation for the smallness of these creatures, they make up in numbers, and it is questionable whether any other class of animals exceed them in importance in the economy of nature. Geological evidence shows that they were the starting-point of animal life in time, and their agency in rock-making has not been exceeded by later higher and more visible forms.

With the marine kind, known as foraminifera, we have been longest familiar. The beautiful many-chambered shells of these—for the most part just visible to the naked eye—form a large portion of the ocean-mud and the sands of the ocean-shore. Shells of foraminifera likewise form the basis of miles of strata of limestone, such as the chalk of England and the limestones of which Paris and the pyramids of Egypt are built.

Fresh-water rhizopods, though not so abundant as marine forms, are nevertheless very numerous. They mainly inhabit our lakes, ponds, and standing waters, but they also swarm in sphagnous swamps, and ever live in newest earth. Professor Leidy has devoted several years of study to the fresh-water rhizopods of the eastern portion of our country, and his especial object in the past expedition was to investigate those which are to be found in the elevated regions of the Rocky Mountains.

The botany of the Survey was represented the past season by the two great masters of that department, Sir Joseph D. Hooker, director of the Gardens of Kew, England, and president of the Royal Society of London; and Prof. Asa Gray, of Cambridge, Mass. Their examinations extended over a great portion of Colorado, Wyoming, Utah, Nevada, and California. Their investigation into the alpine floras and tree vegetation of the Rocky Mountains and Sierra Nevada enabled them to give a clear idea of the relations and influence of the climatic conditions on both sides of the great mountain-ranges.

Sir Joseph Hooker, whose botanical researches embrace the greater part of Europe; the Indies, from the bay of Bengal across the Himalaya's to Thibet; the Antarctic regions and the southern part of South America, New Zealand, Australia, South Africa, Morocco and Asia Minor, presents in the English periodical "Nature" for October 25 an outline of his studies during the season, and this outline when filled out will form a most important report for the eleventh annual Report of the Survey. It will be seen at a glance that the report will be of the most comprehensive character, and cannot fail to be of the highest interest to our people. The tree vegetation, and especially the coniferæ, were made special objects of study, and many obscure points were cleared up.

Of a section of the Rocky Mountains comprising Colorado, Wyoming, and Utah, Dr. Hooker says:

Such a section of the Rocky Mountains must hence contain representatives of three very distinct American floras, each characteristic of immense areas of the continent. There are two temperate and two cold or mountain floras, viz: (1) a prairie flora derived from the eastward; (2) a so-called desert and saline flora derived from the west; (3) a subalpine; and (4) an alpine flora; the two latter of widely different origin, and in one sense proper to the Rocky Mountain ranges.

The principal American regions with which the comparison will have first to be instituted are four. Two of these are in a broad sense humid; one, that of the Atlantic coast, and which extends thence west to the Mississippi River, including the forested shores of that river's western affluents; the other, that of the Pacific side, from the Sierra Nevada to the western ocean; and two inland, that of the northern part of the continent extending to the Polar regions, and that of the southern part extending through New Mexico to the Cordillera of Mexico proper.

The first and second (Atlantic plus Mississippi and the Pacific) regions are traversed by meridional chains of mountains approximately parallel to the Rocky Mountains, namely, on the Atlantic side by the various systems often included under the general term appalachian, which extend from Maine to Georgia, and on the Pacific side by the Sierra Nevada, which bound California on the east. The third and fourth of the regions present a continuation of the Rocky Mountains of Colorado and Utah, flanked for a certain distance by an eastern prairie flora extending from the British Possessions to Texas, and a western desert or saline flora, extending from the Snake River to Arizona and Mexico. Thus the Colorado and Utah floras might be expected to contain representatives of all the various vegetations of North America, except the small tropical region of Florida, which is confined to the extreme southeast of the continent.

The most singular botanical feature of North America is unquestionably the marked contrast between its two humid floras, namely, those of the Atlantic plus Mississippi, and the Pacific one; this has been ably illustrated and discussed by Dr. Gray in various communications to the American Academy of Sciences, and elsewhere, and he has further largely traced the peculiarities of each to their source, thus laying the foundations for all future researches into the botanical geography of North America; but the relations of the dry intermediate region either to these or to the floras of other countries had not been similarly treated, and this we hope that we have now materials for discussing.

Dr. Hooker sums up the results of the joint investigations of Dr. Gray and himself, aided by Dr. Gray's previously intimate knowledge of the elements of the American flora, from the Mississippi to the Pacific coast:

That the vegetation of the middle latitudes of the continent resolves itself into three principal meridional floras, incomparably more diverse than those presented by any similar meridians in the Old World, being, in fact, as far as the trees, shrubs, and many genera of herbaceous plants are concerned, absolutely distinct. These are the two humid and the dry intermediate regions above indicated.

Each of these, again, is subdivisible into three, as follows:

1. The Atlantic slope plus Mississippi region, subdivisible into (α) an Atlantic, (β) a Mississippi Valley, and (γ) an interposed mountain region with a temperate and subalpine flora.

2. The Pacific slope, subdivisible into (α) a very humid, cool, forest-clad coast range; (β) the great, hot, drier Californian valley formed by the San Juan River flowing to the north and the Sacramento River flowing to the south, both into the Bay of San Francisco; and (γ) the Sierra Nevada flora. temperate, subalpine, and alpine.

3. The Rocky Mountain region, (in its wildest sense extending from the Mississippi beyond its forest region to the Sierra Nevada,) subdivisible into (α) a prairie flora, (β) a desert or saline flora, (γ) a Rocky Mountain proper flora, temperate, subalpine, and alpine.

As above stated. the difference between the floras of the first and second of these regions is specifically, and to a great extent generically, absolute; not a pine or oak, maple, elm, plane or birch of Eastern America extends to Western, and genera of thirty to fifty species are confined to each. The Rocky Mountain region again, though abundantly distinct from both, has a few elements of the eastern region and still more of the western.

Many interesting facts connected with the origin and distribution of American plants, and the introduction of various types into the three regions, presented themselves to our observation or our minds during our wanderings. Many of these are suggestive of comparative study with the admirable results of Heer's and Lesquereux's investigations into the Pliocene and Miocene plants of the north temperate and frigid zones, and which had already engaged Dr. Gray's attention, as may be found in his various publications. No less interesting are the traces of the influence of a glacial and a warmer period in directing the course of migration of Arctic forms southward, and Mexican forms northward in the continent, and of the effects of the great body of water that occupied the whole saline region during (as it would appear) a glacial period.

Lastly, curious information was obtained respecting the ages of not only the big trees of California, but of equally aged pines and junipers, which are proofs of that duration of existing conditions of climate for which evidence has hitherto been sought rather among fossil than among living organisms.

Up to the year 1874 rumor had been telling many marvelous stories of strange and interesting habitations of a forgotten people, who once occupied the country about the headwaters of the Rio San Juan, but these narrations were so interwoven with romance that but few people placed much reliance upon them. To those well versed in archæology, ruins of an extensive and interesting character were known to exist throughout New Mexico and Arizona, and the various reports of Abert, Johnson, Sitgreaves, Simpson, Whipple, Newberry, and others form our most interesting chapter in ancient American history; but their researches, aside from the meager accounts published by Newberry, throw no light on the marvelous cliff dwellings and towns north of the San Juan. In 1874 the photographic division of the United States Geological Survey was instructed, in connection with its regular work, to visit and report upon these ruins, and in pursuance of this object made a hasty tour of the region about the Mesa Verde and the Sierra el Late, in Southwestern Colorado, the results of which trip, as expressed by Bancroft, in the Native Races of the Pacific Coast, "although made known to the world only through a three or four days' exploration by a party of three men, are of the greatest importance." A report was made and published, with fourteen illustrations, in the Bulletin of the United States Geological and Geographical Survey of the Territories, second series, No. 1.

The following year the same region was visited by Mr. W. H Holmes, one of the geologists of the Survey, and a careful investigation made of all the ruins. Mr. Jackson, who had made the report the previous year, also revisited this locality, but extended his explorations down the San Juan to the mouth of the De Chelly, and thence to the Moqui villages in Northeastern Arizona. Returning, the country between the Sierra Abajo and La Sal and the La Plata was traversed, and an immense number of very interesting ruins were first brought to the attention of the outside world by the report which was published the following winter by Messrs. Holmes and Jackson, in the Bulletin of the Survey, Vol. II, No. 1.

The occasion of the centennial exhibition at Philadelphia led to the idea of preparing models of these ruins for the clearer illustration of their peculiarities, four of which were completed in season for the opening of the exhibition. Since that time not only the number of these interesting models has been increased, but they have been perfected in execution and faithful delineation of these mysterious remains of an extinct race who once lived within the borders of our western domain.

A visit to the rooms of Mr. Jackson, photographer of the Survey, enables one to inspect in miniature size the dwellings of the Moqui, and in full size a large collection of the ceramics and implements of those ancient and extinct people of our continent. A study of the models will give a very excellent idea of the ruined dwellings themselves. The first of these models, executed by Mr. Holmes, with whom the idea originated, represents the cliff house of the Mancos Cañon, the exterior dimensions of which are 28 inches in breadth by 46 inches in height, and on a scale of 1.24, or two feet to the inch. This is a two-story building, constructed of stone, occupying a narrow ledge in the vertical face of the bluff 700 feet above the valley, and 200 feet from the top. It is 24 feet in length and 14 feet in depth, and divided into four rooms on the ground-floor. The beams supporting the second floor are all destroyed. The doorways, serving also as windows, were quite small, only one small aperture in the outer wall facing the valley. The exposed walls were lightly plastered over with clay, and so closely resembled the general surface of the bluff that it becomes exceedingly difficult to distinguish them at a little distance from their surroundings.

The second model of this series was constructed by Mr. Jackson, and represents the large "cave town," in the valley of the Rio de Chelly near its junction with the San Juan. This town is located upon a narrow bench, occurring about 80 feet above the base of a perpendicular bluff some 300 feet in height. It is 545 feet in length, about 40 feet at its greatest depth, and shows about 75 apartments on its ground-plan. The left-hand third of the town, as we face it, is overhung some distance by the bluff, protecting the buildings beneath much more perfectly than the others. This is the portion represented by the model. A three-story tower forms the central feature; upon either side are rows of lesser buildings, built one above another upon the sloping floor of rock. Nearly all these buildings are in a fair state of preservation. This model is 37 by 47 inches, outside measurements, and the scale 1.72, or 6 feet to the inch. A "restoration" of the above forms the third in the series, of the same size and scale, and is intended, as its name implies, to represent as nearly as possible the original condition of the ruin. In this we see that the approaches were made by ladders and steps hewn in the rock, and that the roofs of one tier of rooms served as a terrace for those back of them, showing a similarity, at least, in their construction to the works of the Pueblos in New Mexico and Arizona. Scattered about over the buildings are miniature representations of the people at their various occupations, with pottery and other domestic utensils.

The "triple-walled tower," at the head of the McElmo, is the subject of the fourth model. It was constructed by Mr. Holmes, and represents, as indicated by its title, a triple-walled tower, situated in the midst of a considerable extent of lesser ruins, probably of dwellings, occupying a low bench bordering the dry wash of the McElmo. The tower is 42 feet in diameter, the wall 2 feet thick, and now standing some 12 feet high. The two outer walls inclose a space of about 6 feet in width, which is divided into 14 equally-sized rooms, communicating with one another by smal window-like doorways. The next is a "cliff-house" in the valley of the Rio de Chelly. It is about 20 miles above the cave town already spoken of. This is a two-story house, about 20 feet square, occupying a ledge some 75 feet above the valley, and overhung by the bluff. The approach from the valley is by a series of steps hewn in the steep face of the rock; and this method was the one most used by the occupants, although there is a way out to the top of the bluff. This model is 42 inches in height by 24 broad, and is built upon a scale of 1.36.

Téwa, one of the seven Moqui towns in Northeastern Arizona, is a very interesting and instructive model, representing, as it does, one of the most ancient and best authenticated of the dwellings of a people who are supposed to be the descendants of the cliff-dwellers. Téwa is the first of the seven villages forming the province as we approach them from the east, and occupies the summit of a narrow mesa some 600 feet in height and 1,200 yards in length, upon which are also two other somewhat similar villages. The approach is by a circuitous roadway hewn in the perpendicular face of the bluff, which surrounds the mesa upon all sides. It is the only approach accessible for animals to the three villages. Other ladder-like stairways are cut in the rock, which are used principally by the water carriers, for all their springs and reservoirs are at the bottom of the mesa. This village is represented upon a scale of 1 inch to 8 feet, or 1.96. The dimensions of the model are 36 inches in length, 29 inches in width, and 14 inches in height.

In the spring of 1877, Mr. Jackson made a tour over much of the northern part of New Mexico, and westward to the Moqui towns in Arizona, and secured materials for a number of very interesting models, illustrating the methods of the Pueblos or town-builders in the construction of their dwellings. Two villages have been selected for immediate construction, as showing the most ancient and best known examples of their peculiar architecture, viz, Taos and Acoma; the one of many-storied, terraced houses, and the other built high upon an impregnable rock. The model of Taos is now completed, the dimensions of which are 42 by 39 inches, and the scale one inch to twenty feet, 1:240.

Of this town Davis says:

> It is the best sample of the ancient mode of building. Here are two large houses three or four hundred feet in length, and about one hundred and fifty feet wide at the base. They are situated upon opposite sides of a small creek, and in ancient times are said to have been connected with a bridge. They are five and six stories high, each story receding from the one below it, and thus forming a structure terraced from top to bottom. Each story is divided into numerous little compartments, the outer tier of rooms being lighted by small windows in the sides, while those in the interior of the building are dark, and are principally used as storerooms. * * * The only means of entrance is through a trap-door in the roof, and you ascend from story to story by means of ladders on the outside, which are drawn up at night.

Their contact with Europeans has modified somewhat their ancient style of buildings, principally in substituting doorways in the walls of their houses for those in the roof. Their modern buildings are rarely over two stories in height, and are not distinguishable from those of their Mexican neighbors. The village is surrounded by an adobe wall, which is first included within the limits of the model, and incloses an area of eleven or twelve acres in extent. Within this limit are four of their *estufas*, or secret council-houses. These are circular underground apartments, with a narrow opening in the roof, surrounded by a palisade, ladders being used to go in and out.

These models are first carefully built up in clay, in which material all the detail is readily secured, and are then cast in plaster, a mold being secured by which they are readily multiplied to any extent. They are then put in the hands of the artists and carefully colored in solid oil paints to accurately resemble their appearance in nature, and, in the case of restorations or modern buildings, all the little additions are made which will give them the appearance of occupation. The survey is in possession of the data for the construction of many more models, and they will be brought out as opportunity is given. They have also, in connection with the views, multiplied many of the curious pieces of pottery which have been brought back from that region by the various parties connected with the survey.

During the season of 1877 it was found impracticable to place a separate party in the field for zoölogical work, as Dr. Elliott Coues, the naturalist of the Survey, was fully occupied during the summer at the Washington office in the care of the numerous publications of the Survey which have appeared during the present year.

Very respectfully, your obedient servant,

F. V. HAYDEN,
United States Geologist.

Hon. CARL SCHURZ,
Secretary of the Interior, Washington, D. C.

PRELIMINARY REPORT

OF THE

FIELD WORK OF THE UNITED STATES GEOLOGICAL AND GEOGRAPHICAL SURVEY OF THE TERRITORIES FOR THE SEASON OF 1878.

By F. V. Hayden.

Office Geological and Geographical
Survey of the Territories,
Washington, D. C., December 1, 1878.

Sir: I have the honor to present for your consideration a brief summary of the field work of the United States Geological and Geographical Survey under my charge, for the season of 1878.

Owing to the length of the session, Congress did not pass the usual appropriation for the work of the survey until July, and consequently the field labor was of comparatively short duration.

The headquarters of the survey was at Cheyenne, Wyo., the same as the preceding season. Four parties were organized, but in such a manner that in case of necessity they could be divided for special duty. All our outfit and animals were transported from Cheyenne to Point of Rocks and Green River Stations, on the Union Pacific Railroad, and from thence the parties pursued their way northward to their respective fields of labor.

To the first division, in charge of A. D. Wilson, was confided the primary triangulation of the entire area to be surveyed. Eight of the most important peaks were employed as stations, with some minor points. Among the more important stations were Wind River, Fremont's, Grand Teton, and Sawtelle's Peaks (near Henry's Lake); also several of the most conspicuous points in the Yellowstone Park. This division was robbed, near Sawtelle's Peak, of all its animals and a portion of its outfit, so that at least half of the most valuable time for work during the season, was lost. Had it not been for this misfortune at least double the work would have been accomplished. The Yellowstone Park at this time forms the most extensive unoccupied area in the West, and, surrounded by great ranges of mountains, becomes a resort for hostile bands of Indians when pursued by the troops.

To the division of the survey in charge of Mr. Henry Gannett was intrusted the work of making a specially-detailed geological and geographical survey of the Yellowstone National Park. The party was divided into two sections for the prosecution of this work; one section, consisting essentially of Mr. Gannett, topographer, and Mr. W. H. Holmes, geologist, made the general survey of the park, while the other, consisting of Dr. A. C. Peale and Mr. J. E. Mushbach, were occupied in making detailed studies and maps of the geyser and hot-spring localities, a work of the greatest interest and value to the scientific world.

Material was secured for a detailed map, on a scale of one mile to an inch, of the Yellowstone Park, an area of 3,500 square miles; and for maps on a large scale of all the principal geyser and hot-spring localities. In the survey of the park, forty-seven important stations were occupied for secondary triangulation and topography, besides a large number of lesser importance. On all the principal stations, stone monuments were erected for future reference. Several groups of geysers and hot springs, not heretofore known, were discovered.

The area of the Yellowstone Park is, in round numbers, 3,500 square miles. Its surface is in large part level or rolling, with several groups and short ranges of mountains diversifying it. In the eastern part, extending its whole length and forming the water-shed between the Yellowstone and the Bighorn, stand the rugged volcanic peaks of the Yellowstone Range. Nearly all of the park is covered with a dense growth of magnificent pine timber; indeed, west of the one hundredth meridian there is no area so densely timbered with the exception of Washington Territory. The mean elevation of the park above sea-level is between 7,000 and 8,000 feet, which implies too cold a climate to admit of agriculture, except in certain very limited localities. It is safe to say that not more than one per cent. of this area can, by any possibility, be used for agricultural purposes. Except along the northern border, grazing land exists only in small patches of a few acres each. There are not, so far as is known, any mines or mineral deposits within the park.

The only occupied buildings within the park are at the White Mountain Hot Springs, where Mr. J. C. McCartney has made some improvements. A good wagon-road extends from Bozeman, Mont., to this point. From these springs, which form the usual point of departure for excursionists, there are excellent trails to all points of interest within this region; to Amethyst Mountain, Yellowstone Falls and Lake, the Mud Geysers, and other objects of interest on Yellowstone River and the Geyser Basins. It is unnecessary to specify these trails, as they traverse the country in all directions. In his campaign against the Nez Percés, in 1877, General Howard constructed an excellent wagon-road up the Madison to the Lower Geyser Basin, and thence across to the Yellowstone. His road up the Yellowstone is impassable at present for wagons.

Mr. W. H. Holmes acted as geologist to the second division. The first month of the season he was with the fourth division, which proceeded from Point of Rocks Station northward, along the west side of the Wind River Mountains, and up the Snake River Valley to the Yellowstone Park, where he joined the second division. In the mean time he was engaged in making sketches, panoramic views, and geological sections of the intermediate country, all of which will prove of the highest importance in illustrating the geological structure of this most interesting and complicated region.

The latter part of the summer was spent in making detailed geological examinations in the district that includes the National Park. The greater portion of the park was found to be covered with somewhat uniform flows of the ordinary volcanic rocks. Features of more than ordinary geologic interest occur, however, along the northern border of the park district. Here a small belt, not more than 15 by 30 miles in extent, contains a fair epitome of the geology of the Rocky Mountain region. The whole series of formations from the earliest to the most recent are almost typically developed. The only marked irregularity in the succession of geologic events occurred during the great mountain-building period of the Middle Tertiary. After that followed a number of inferior oscillations of the surface, during which an extensive series of recent Tertiary and volcanic rocks were deposited. Connecting this period with the present are the deposits of a number of great lakes, which at the present time have their chief representative in Yellowstone Lake. Detailed investigations were made at many points of interest, and a fine mineralogical collection was made.

In the mean time Mr. Holmes sketched every square mile of the park, an area of 3,500 square miles. In such minute detail was the work done that the economic resources, as well as all the minor features of the geology, can be laid down on a map on a scale of one mile to an inch with the greatest care and minuteness. The great variety of forms which the mountains in and around the park assume can be presented to the eye by panoramic views with wonderful distinctness.

The third division, under Mr. F. A. Clark, surveyed the Wind River Mountains, a portion of the Wyoming Range, the Gros Ventres Range, with a large area in the Snake River Valley. Mr. Clark made 31 gradienter stations and 15 compass stations. The area lies between latitude 43° and 44° and longitude 109° 15′ and 111°. This includes the upper portion of the Wind River Mountains, with portions of the Wyoming ming Range, the Gros Ventres Range, and portions of the Shoshone Mountains and the Owl Creek Range; also the sources of Green River, Hoback Basin, and upper waters of Wind River. Mr. St. John acted as geologist and Mr. N. W. Perry as mineralogist to this party. Their reports will prove of general interest. Mines of gold, silver, iron, and vast beds of gypsum, as well as many other minerals, were found.

In the prosecution of the field-work of the survey during the past season a photographic division was again put in operation, after an interval of two years, under the leadership of Mr. W. H. Jackson, who has been connected with the survey as its photographer during the past nine years.

Leaving Point of Rocks, on the Union Pacific Railroad, on July 24, the first points of interest were reached on the western flank of the Wind River Mountains. Two side trips, undertaken in connection with Mr. Wilson, in charge of the primary triangulation, were made to the crest of the range, and some grand views of that remarkable region were obtained. From the summit of Frémont's Peak views were made of an immense glacier now occupying its eastern slope. Fine views were also obtained of the great glaciated plateau lying between the plains and the crest of the range.

Proceeding next to the vicinity of the Grand Tétons, lying to the east of the headwaters of the Snake River, several magnificent views of the remarkable range in which they occur were made from the neighborhood of Jackson's Lake.

Reaching Shoshone Lake the 18th of August, the entire month following was devoted exclusively to the careful photography of all the remarkable phenomena connected with the hot springs and geysers of the various basins within the Park. Especial attention was paid to the almost unknown but exceedingly interesting features of the new Shoshone and Red Mountain Basins. The "Fire Hole" and "Mammoth Hot Spring" Basins were again gone over, and the experience derived from the work done here in former years shows its benefits in the remarkably effective views obtained this season. At this latter basin many detailed as well as general views were made with especial reference to the future production of an exact model in plaster of the whole group.

On the homeward route, which was by the way of the Upper Yellowstone, across the headwaters of the Snake to the Wind River and thence via Camp Brown to the railroad, a number of very effective views were made, particularly about the Grand Falls and the cañon of the Yellowstone. At the Yellowstone Lake some very fine views were made, but that region was left somewhat incomplete in consequence of a prolonged snow-storm.

As the Togwotee Pass some characteristic views were obtained of the remarkable breccia mountains, whose castellated forms adorn that portion of the continental divide, and also some of the curious "bad lands" farther down on Wind River. The season's work closed at Camp Brown, where some excellent portraits and groups were made of the Bannock prisoners in confinement at that post.

A brief summing up of the season's operations of three months, much of which time was characterized by extremely inclement weather, shows an increase to the already very extensive collection of the survey, of 45 negatives 11 by 14 inches in size, and 110 of smaller ones, 5 by 8. The number was purposely kept small that a better quality might prevail in them.

The geologist in charge accompanied the photographic division, and the route pursued gave him an opportunity to secure a very accurate general knowledge of the geological structure of a large area. The Wind River Range proved one of remarkable interest. It has a trend about northwest and southeast, with a length of about 100 miles. On the west side all the sedimentary belts have been swept away, down to the Archæan, older than the Wahsatch, and the latter formation rests on the Archæan rocks all along the base of the range, seldom inclining more than 5° to 10°. On the east side of the range the seams of sedimentary formations usually known to occur in the northwest are exposed from the Potsdam sandstone, which rests upon the Archæan rocks, to the Cretaceous inclusive.

Along the northwestern portion of the range the Wahsatch Group only is seen for some distance, but as we proceed down the Wind River Valley the formations appear one after the other, until at the lower end the entire series is exposed. The Wind River Range may be regarded as originally a vast anticlinal, of which one side has been entirely denuded of the sedimentary, except the Middle Tertiary. On the same side of the range the morainal deposits and glaciated rocks are shown on a scale such as we have not known in any other portion of the West. Three genuine glaciers were discovered on the east base of Wind River and Frémont Peaks, the first known to exist east of the Pacific coast.

The morainal deposits are also found on a grand scale in the Snake River Valley, on the east side of the Teton Range. The numerous lakes have been the beds of glaciers, and the shores of the lakes are walled with morainal ridges. North of the Teton Mountains the prevailing rocks are of modern volcanic origin, and in the Yellowstone Park the hot springs and geysers are the later manifestations of the intense volcanic activity that once existed. All these interesting features were studied with care, and the results will be elaborated for the twelfth annual report of the survey.

It was with great pleasure that the geologist in charge reviewed the ground passed over in 1860, over eighteen years previously. In the years 1859 and 1860 he acted as geologist to the exploring expedition under the command of Col. William F. Raynolds, now of the Engineer Corps, U. S. A. A portion of the geological report made on that expedition will be reprinted in the 11th annual report.* A geological map accompanies this report, which embraces Dakota and Montana, with portions of Idaho, Wyoming, and Colorado.

*Geological Report of the Exploration of the Yellowstone and Missouri Rivers, under the direction of Capt. (now Lieut. Col. and Brevet Brig. Gen.) W. F. Raynolds, Corps of Engineers, 1859-1860. By F. V. Hayden.

The publications of the survey during the past year have been numerous and important. The atlas of Colorado, in twenty sheets, has received the most unqualified praise for its accuracy and beauty, both in this country and in Europe. The following analysis of the atlas was written for the London periodical "Nature," of September 12, by Prof. Archibald Geikie, director of the geological survey of Scotland and professor of geology in the University of Edinburgh, and one of the ablest geologists in Europe:

In the magnificent atlas just issued by the Department of the Interior we have the consummation and crown of all the labors which Dr. Hayden and his staff have carried on so triumphantly for the last five years, and of which they have already given us so much interesting and important information in a series of annual reports. Before examining the work from a scientific point of view, no reader can refrain from expressing his admiration of the style in which the atlas has been produced by the United States Government. As a specimen of cartography, typography, and lithography it is altogether worthy of the highest praise. For beauty and, indeed, sumptuousness of execution, it may be classed with those *livres de luxe* which from time to time have been issued from the National Imprimerie of France.

The atlas consists of two series of maps, the one of a general, the other of a detailed kind. The first series, on the scale of twelve miles to one inch, comprises four sheets, each embracing the whole State of Colorado and part of the neighboring territory. The first of these illustrates the system of triangulation adopted in the survey; the second shows the drainage system of the area; the third, by a simple and clear arrangement of colors, exhibits at a glance the economic features of the whole region—the agricultural land, pasturage, forests and woodlands, sage and bad lands, mineral tracts, and the portions rising above the limit of timber-growth; the fourth contains a condensed and generalized geological map of the same territory. Nothing can surpass the lucidity of expression and artistic finish of these maps.

The second series—twelve in number—is on the scale of four miles to one inch, and consists of six topographical sheets and six identical sheets, colored geologically. The topographical details, though numerous, are so selected as not to neutralize each other or mar the broad, clear picture which the maps were designed to be. By means of contour-lines of 200 feet vertical distance, the surface-configuration of the whole region is depicted as in a model. We can follow the lines of the broad valleys, of the deep, narrow cañons, and of the hundreds of minor tributaries which have scarped out their courses on either side. Here we look down upon a vast table-land, deeply trenched by stream-channels; there upon a succession of bold escarpments or mesas, which bound the table-land and hem in the neighboring valley. Huge mountain-ranges rising out of the plateaus are so vividly drawn that they seem to stand out of the paper; yet no shading is employed. All the effects of inequality are produced by contour lines, so faithfully set down that a single line may be tracked in its sinuous course along the whole of a mountain front until it comes out upon the table-land beyond. When will our map-makers learn to use this, the only true method for expressing the surface of a country? The best of our atlases are disfigured by strips of shading running across the map, like so many caterpillars, to represent mountain ranges. Even our ordnance maps, so admirable in most respects, are sometimes so loaded with shading that a steep hillside, only a few hundred feet high, is made as black as our highest mountains, and the topographical names can hardly be read, even with a magnifying-glass.

But, above all, welcome are these six geological maps. In the previously published maps and charts accompanying the annual reports only small detached areas were represented, and even from the careful descriptions of the various geologists of the staff, it was hardly possible to frame a satisfactory conception of the geology of Colorado as a whole. Ever since the marvels of its deep gorges and vividly painted cliffs were made known, that region has possessed a high interest to the geologist. He has now the means of gratifying his desire for further knowledge. With the help of these maps and the two accompanying sheets of sections, he can realize most satisfactorily every great feature of Colorado geology. The ancient Archæan ridge—the nucleus or backbone of the American Continent—may be traced running north and south nearly along the present hydrographical axis of the country. Flanking that ridge comes a series of Palæzoic deposits, the oldest of which have been identified palæontologically with Silurian formations. Rocks regarded as of Devonian age overlap the Silurian beds, and repose against the ancient crystalline ridge on the southwest side of the San Juan Mountains. They are soon buried under later accumulations, and they seem to be of but local development, since in most places where the rocks are found in juxtaposition, the Silurian are directly succeeded by Carboniferous strata. These last-named rocks cover large tracts of country, running as bands round the Archæan area, and lying in basins across it. Far to the west, where the Grand River has so deeply trenched the Utah plateau, the flat Carboniferous beds appear from under the brilliant red Triassic strata. The difficulty of drawing any line between Triassic and Jurassic formations in that region is again acknowledged on these maps, the lower red series being doubtfully assigned to the older, and the upper variegated deposits to the latter system.

Cretaceous rocks are abundantly developed, and cover a vast extent of territory. In particular, they spread over the wide plateaux between the San Juan and Gunnison Rivers, and form the platform on which the enormous volcanic outbursts have been piled up from the West Elk Mountains southward into New Mexico. It is more easy to trace on these maps, too, the area respectively occupied by the Laramie, Wasatch, Green River, Bridger, and Uintah formations which represent Post Cretaceous and Tertiary times. Glacier moraines, lake deposits, drifts, sand-dunes, and recent alluvia, all find adequate expression on the maps. Especial care, too, seems to have been bestowed upon the eruptive rocks which form so important and interesting a feature of Colorado geology. The more characteristic varieties are represented by distinct shades of crimson or orange, and they have been mapped in such a way as to convey at a glance, and even without the aid of sections, a tolerable clear notion of the volcanic phenomena of the region. On the one hand we see the great lava-sheets capping the mesas and spreading far over the plateaux; on the other, we notice the great centres of volcanic activity, with their abundant flows, dikes, and breccias.

Two sheets of sections, drawn across all the more interesting and important portions of the geology, complete the vast fund of information given by the maps; while, that nothing may be wanting to enable readers to realize what has been done by the survey, and the conditions under which it has been accomplished, two large sheets of sketches are given, which most vividly represent the forms of the mountains, plateaux, mesas, and river channels as seen from various commanding heights.

Dr. Hayden, with whose personal supervision this great work has been accomplished, has increased tenfold the obligations under which he has laid geologists all over the world for the number and value of his contributions to geology. He now furnishes us with new light whereby to read his former researches and those of his able colleagues. May we venture to hope that he may find leisure to confer yet one further benefit before the progress of his survey plunges him into a new whirl of work? If he could be prevailed upon to sketch out a plan for digesting the materials of his published annual reports, he could doubtless find among his staff some competent writer who, under his guidance, could produce a well-arranged systematic guide-book or text-book to complete the value of the work of his survey. Such a book of reference as would give a reader who has never had access to the annual reports a clear and comprehensive view of Colorado geology would be of great service.

These remarks may be fitly closed with an expression of the warmest admiration of the liberal spirit in which the United States Government has conducted these surveys of the Territories and has published their results. This costly atlas has been distributed gratuitously all over Europe. That this is a wise policy cannot be doubted. Whether actuated or not by a desire to diffuse scientific information, the authorities at Washington do well to make as widely known as possible the geological structure and economic resources of their country. They cast their bread upon the waters and the harvest comes to them in the form of eager, active emigrants from all parts of Europe.

The Bulletin of the Survey has now reached the close of the fourth volume, which contains 37 articles and about 900 octavo pages. The tenth annual report embraces 550 closely printed pages, octavo, with 80 plates, maps, sections, &c. About 50 of the plates illustrate the remarkable cliff-dwellings which were found by the members of the Survey along the cañons of the streams of Southern Colorado and New Mexico. Volume IV, quarto, on the Miocene and Pliocene vertebrates of the West, by E. D. Cope, and Volume XII, by Dr. Joseph Leidy, on the Rhizopods, are far advanced, and will be ready for distribution in the spring. The eleventh annual report is in press; about 300 pages already in type. This volume will be issued early in the spring.

The members of the Survey are now all in the office from their field-work, and busily engaged in elaborating their field-notes. The materials for the twelfth annual are very ample and of great interest.

Very respectfully, your obedient servant,

F. V. HAYDEN,
United States Geologist.

Hon. CARL SCHURZ,
Secretary of the Interior.

APPENDIX.

The following articles on the geology of the Rocky Mountain region were published in the American Journal of Science, New Haven, Conn., several years ago, and are now entirely out of print. Inasmuch as they contain some views that have either been absorbed or overlooked by modern geologists, they are reprinted in this connection. There are some views that, if written at this time, might be restricted or modified, but in the main they are correct. The articles are reprinted without any alteration.

SOME REMARKS IN REGARD TO THE PERIOD OF ELEVATION OF THOSE RANGES OF THE ROCKY MOUNTAINS NEAR THE SOURCES OF THE MISSOURI RIVER AND ITS TRIBUTARIES.

BY DR. F. V. HAYDEN.*

[From the American Journal of Science, vol. xxxiii, May, 1862.]

The object of the present article is to show, as nearly as can be done from known geological data, the period of the elevation of a portion of the Rocky Mountains. My observations have been more especially confined to the ranges from which the Missouri and Yellowstone Rivers, with their numerous tributaries, take their rise, though I feel confident that principles which will apply to mountains occupying so large an area will also be applicable to the whole Rocky Mountain district. It will be impossible, at this time, to mention in detail all the facts in support of my statements, and therefore I shall assume that the reader has examined the previous papers of my associate, Mr. Meek, and myself. During the coming year I hope to prepare a series of articles for this journal which will have a more or less direct bearing on the physical geography of this region and the influences which gave to it its present configuration. Some erroneous statements, growing out of our limited knowledge of the structure of these mountain chains, may be made, but these, when known, will be corrected. Geology is a progressive science, and even our best efforts are but approximations to truth rather than the truth itself.

The evidence seems to me to be clear that the great subterranean forces that elevated the western portion of our continent were called into operation toward the close of the Cretaceous epoch, and that the gradual quiet rising continued, without a general bursting of the earth's crust, until after the accumulation of the Tertiary lignite deposits, or at least the greater part of them; also, that after the fracture of the surface commenced and those great crust movements began to display themselves, the whole country continued rising, or at least, though there may have been periods of subsidence or repose, there was a general upward tendency, which has continued even up to our present period. I hope hereafter to illustrate the correctness of these statements by all the facts that have been obtained in my past explorations as well as by those I may secure in the future.

Let us, in the first place, examine some of the barometrical profiles across the country from the Mississippi River to the Pacific coast, constructed under the direction of the War Department. Previously, however, to this examination we may make the statement that west of longitude 98° the surface of the country may be separated into two divisions, mountain and plain, and that a combination of the two compose the Rocky

*For most important information I would direct attention to second series of this journal, articles xiii, xxxix, vol. iii, 1847, article xxxiv, vol. xii, 1849, and articles xxiv, xxv, vol. xxii, 1856, by Prof. J. D. Dana, in which, it seems to me, will be found the most profound, far-reaching generalizations in regard to the physical geography and geology of the West and other portions of our country which have ever been given to the public. The origin and character of those subterranean forces which have produced such important results in the West are fully discussed in those papers.

Mountain district. After leaving the Mississippi the intervening country westward to the upheaved ridges is an apparently level or undulating plain, with no disturbance of the strata of the underlying formations until we come in close proximity to some of the mountain elevations. Reaching the base of the elevated ridges which form the mountain crests, we at once commence a rugged and abrupt ascent.

If we look at the profile constructed by Governor Stevens, from Saint Paul, Minn., latitude 44° 58′ and longitude 92° 58′, to the Pacific coast, we shall find that the starting point is 828 feet above the ocean-level. Near Fort Union, at the junction of the waters of the Yellowstone and Missouri, 670 miles westward, the height above the ocean-level has increased to 2,010 feet, or 1,182 feet higher than Saint Paul. We thus see that the average ascent of the country between these two points is not quite two feet to the mile. From Fort Union to the valley of Dearborn River, just under the base of the elevated ridges of the principal eastern range, we find the distance to be 448 miles and the height above the ocean 2,081 feet greater then that at Fort Union, or the average rate of ascent increased to nearly five feet per mile. Over this vast extent of country extends an almost limitless prairie, apparently level, with no forests or groves, with no timber except that which skirts the streams. There is in this great distance a gradual increase in the inclination of the strata proportioned to the increase of the ascent, but no marked disturbance of the beds until we arrive in close proximity to the mountain elevations. There are a few local fractures of the earth's crust caused by the elevation of the Bear's Paw, Little Rocky Mountain, &c., around which the sedimentary rocks are more or less disturbed, but all these lesser mountains are more or less remotely connected with the main chain. After passing the highest point of the principal range, along this line, which is near Cadotte's Pass, we commence our descent toward the Pacific very much as we ascended the eastern slope, but over a much more rugged route. We find a continued series of more or less parallel ridges of elevation until we approach the coast for a distance of from 400 to 600 miles. From Fort Walla Walla to the ocean, however, the average descent is a little less than one foot to the mile.

Again, if we examine the profile constructed by Frémont, commencing at the mouth of the Kansas River, we find that the initial point is 690 feet above the ocean. Proceeding westward, the average grade for the first 300 miles is between 4 and 5 feet per mile. Thence to Fort Laramie the ascent, as stated by Frémont, is 8 feet to the mile, and from Fort Laramie to Hot Spring Gate, although still passing over prairie country, the average grade of ascent is given by the same explorer as 45 feet per mile. Over this entire route, however, loaded wagons have been transported with ease. When we reach the foot of the mountains in this direction, the lofty elevated ridges seem to rise abruptly out of the prairie, averaging from 1,000 to 6,000 feet in height above the surrounding country. From thence to the Pacific coast we pass over a continued series of elevations which taken in the aggregate seem to trend nearly northwest and southeast, but which, when examined in detail, often present no definite direction or continuous line of fracture. This mountain region is composed of a series of these ridges forming a belt or zone 400 to 800 miles in width from east to west, interspersed with beautiful valleys through which wind streams of clear water. So numerous are the profiles which have now been made across the continent by different explorers that it is hardly necessary to describe each one, since what we have already said indicates the object in view.

We have said that the western portion of our continent, especially if we look only at the easterly slope, may very properly be divided into mountain and prairie. It is true that in Kansas and Iowa, groves of timber of considerable size are seen, but they form rather the exception than the rule. Along the eastern slope there is a belt of country 300 to 600 miles in width, where, for the most part, the only timber to be seen is a thin fringe bordering the streams. Even in the eastern portion of the main range the timber is not luxuriant, like that so common along the coast of Oregon and California. The pine trees are seldom more than 3 feet in diameter.

Again, we may divide the mountains or elevated ridges which form the different ranges into two kinds, viz, those with long extended lines of fracture, with a granitic nucleus and a comparatively regular outline, and those which appear to be composed of a series of cones or peaks more or less intimately connected, exceedingly irregular in their outline and of eruptive origin. Of the first class, the Black Hills, Bighorn, Laramie, and Wind River Mountains are good examples, while the Wahsatch, Green River, Teton Ranges, and many others west of the dividing crest might be cited as illustrations of the second class. From all the information within our reach we have inferred that after passing the eastern slope the mountain ranges of eruptive origin are far the most numerous. We also know from personal observation that the main range of the Rocky Mountains and the subordinate ridges on either side, near the headwaters of the two principal branches, the Yellowstone and Missouri, are of similar origin and present similar rugged features.

We may now return to the Cretaceous period. In a previous paper in this journal,*

* Vol. xxxi, March, 1861.

we remarked that there were no indications in the geological formations of that portion of the West over which we have traversed of long-continued deep-water deposits until we pass up into the Cretaceous epoch. The lower portion of No. 1, or the Dakota Group, which ushered in the Cretaceous epoch in this portion of the West, is composed of coarse sand, pebbles, &c., with ripple marks, oblique laminæ, and with other indications of shallow water and change of currents. The same characters are seen throughout the formation wherever it is exhibited. We also know from the numerous impressions of leaves, and some beds of impure lignite, that dry land could not have been far distant. But as we pass up through Nos. 2, 3, and 4, whatever changes of land may have occurred in the mean time, we think there were periods at least when the sea was of considerable depth and suffered a quiet deposition to go on. We infer this from the fine and homogeneous character of the sediments. Throughout No. 4 we have a fine plastic clay which continues up into No. 5, when a gradual change takes place from the introduction of yellowish ferruginous matter, and a slow increase of sandy sediments. Toward the middle of No. 5 the sand begins to predominate until the upper part becomes a coarse ferruginous sandstone, with all the indications of shallow-water deposits. We know, also, from fragments of wood and impressions of leaves which have been found quite widely distributed in the upper part of No. 5, that dry land could not have been far away. We also infer from the character of the molluscan remains that the great Cretaceous sea which had so long spread its vast waters over this region was becoming shallow, and that a new epoch was approaching. As we arise in No. 4, and pass up into No. 5, there is an evident increase in the number of gasteropoda, indicating shoal waters. We have already remarked their peculiar Tertiary aspect, which seemed to point directly to that epoch, showing that it was not far distant. We may now ask the cause of this apparent approach to land, as foreshadowed by the lithological as well as the paleontological characters of the Upper Cretaceous formation No. 5. We think that the facts indicate that during the deposition of this formation the western portion of the continent was slowly rising above the ocean level, the waters on the one side receding toward the Pacific, and on the other toward the Atlantic, introducing the great Tertiary epoch which had already been foretold in the Cretaceous. At the commencement of the Tertiary period, throughout the central portions of the continent, lakes, estuaries, &c., more or less salt, at length becoming brackish, and finally fresh water, existed, and a new flora and fauna were introduced. The subterranean expansive power which was quietly lifting up the country still continued, although no bursting of the earth's crust had commenced. These brackish water-deposits, which appear to mark the dawn of the Tertiary period in the West, are distributed quite widely over the central portions of the Rocky Mountain district, and then, by a general subsidence or a vast increase of fresh water, the true lignite deposits spread themselves over large areas and probably covered much of the country now occupied by the mountain ranges, and were doubtless more or less intimately connected with the Tertiary beds on the Pacific coast. What barriers separated them from the Tertiary formations along the Pacific it is impossible from our present limited knowledge of the geology of the intermediate region to determine.

We have remarked that the probable period of the bursting of the earth's crust which resulted in the formation of those abrupt mountain crests or ridges, occurred somewhere near the close of the accumulation of the true lignite deposits. We believe this for the following reasons: Whenever we observe the lignite beds in the vicinity of the mountain ranges we find them more or less inclined in the same direction with the older fossiliferous rocks, though, as a general rule, dipping at a smaller angle, because more remote from the axis of the disturbing power. Of course, as the land was slowly elevated toward the surface of the waters, the newer Tertiary beds would be subjected to the erosive action of water first, and thus continuing downward, as the mass was slowly rising, until the granitic nucleus was exposed. The Tertiary rocks, being composed for the most part of loose, yielding material, sands, clays and lignites, would be worn away from the surface for some distance from the axis of elevation. Although the lignite Tertiary beds are developed in full force all along the base of the larger ranges of mountains, it is not unlikely that some of these ridges formed barriers or lofty shores to these great Tertiary lakes. It would seem as if this country during the Tertiary period was not unlike the Undine region of the north, so called by the geographer Nicollet on account of the great number of fresh-water lakes distributed over that district.

Near the Black Hills these beds are worn away from the immediate base of the mountains, and it is doubtful from any proofs that we can now obtain whether the Tertiary lake extended over the country at that time occupied by the Black Hills. West of this range, the lignite Tertiary beds incline from the western slope 5 to 10 degrees. All along the Bighorn Mountains, the same features, only more strongly marked, are seen. These beds often lie quite high upon the slopes of the mountains, conforming to the Cretaceous rocks and sometimes inclining at a high angle. Between the western extremity of the Bighorn Range and the Sweet Water Mountains on the North Platte they are more disturbed than at any other locality. The lignite Tertiary strata are nearly vertical and the hard layers of sandstone or limestone extend in long projecting lines across the country, while the intermediate yielding beds of clay, sand, and lignite are smoothed and leveled by atmospheric agencies and clothed with a thick turf of grass. All along the Laramie Range, from the Red Buttes to Deer Creek, until the lignite beds are concealed by the White River Group, the same features are seen, though the strata incline less, being more remote from the anticlinal crest. On both sides of the Wind River Mountains the same phenomena occur, and other examples might be cited pointing to the same conclusions, but enough has been said to show that it is probable that the lignite Tertiary beds partook of the same movements that have elevated the older fossiliferous rocks. We therefore infer that the fracture of the earth's crust in this portion of the West, by which the nucleus of the mountains was revealed, occurred near the time of the accumulation of the lignite deposits or at the close of that epoch.

Again, although there is not a strict unconformability between the true lignite beds and the Wind River Group, the latter incline in the same direction, only at a much smaller angle. Near the source of Wind River the Wind River Group rests directly upon Cretaceous formation No. 2. At this point the Cretaceous rocks incline from 10° to 25°, while the Wind River beds dip from 1° to 5°. As we ascend the valley of Wind River towards its source, we pass, for a long distance, the steeply inclined Cretaceous and Jurassic rocks, along the margins of the mountains on our left hand, while on our right, but a few hundred yards distant, the naked, almost vertical walls of the lower portion of the Wind River Group* are seen, the strata, however, seldom inclining more than one degree.

The same examples may be observed on the west side of the Wind River Mountains, where the Wind River beds lie high upon the sides of the western slope in a very slightly inclined position and in some localities covering the very summit, showing clearly that even the dividing crest of the mountains was beneath the waters during the deposition of this group. Along the margins of both the Wind River and the Bighorn Mountains these beds seem to have risen in an undisturbed or in a nearly horizontal condition. We have already expressed the opinion in a previous paper,† that the Wind River Group was intermediate in age between the lignite Tertiary and the White River beds, and in point of time filled up a chronological chasm. We have inferred this from the fact that these beds seem to possess paleontological and lithological characters intermediate between the two. They contain casts of a species of *Vivipara* which is undistinguishable from *V. trochiformis*, and fragments of a *Trionyx* apparently the same with that occurring in the lignite beds, also fragments of a *Testudo* which, so far as we can determine, is identical with the *T. Nebrascensis* of the White River beds. If we look also at the composition of the Wind River beds, we find that their light color, indurated arenaceous and argillaceous character, and their general appearance after erosion, favor the correctness of the inference in regard to their intermediate position. From the facts before us in regard to this group, we conclude that even after the crust broke, the country continued slowly rising while the Wind River deposits were accumulating, and that the upper portions when not eroded away were elevated high upon the sides of the mountains in a nearly horizontal position.

Again, the White River beds hold a similar position with reference to the lignite formations as the Wind River Group. They are seldom disturbed, and only in a few instances do they incline as much as 5°. They, however, occur high up on the mountain slopes along both sides of the Laramie Range, showing that they partook of the gradual elevation of the country, after the crust was broken and the mountain district began to approach its present configuration. On the west side of the Black Hills, where the White River beds probably began their origin, we find only the lower strata of this group, usually reposing directly upon Cretaceous rocks, though in a few localities upon lignite formations. But as we descend south and southwestward, these lower beds disappear and more recent ones take their place, until they pass into the Pliocene sands of the Loup River Group, and then, in turn, still farther southward, are lost in the Loess or yellow marl deposits. We can only account for these phenomena on the supposition that this great Tertiary fresh-water lake had its commencement in the White River Valley, and as the Black Hills, and of course the whole Rocky Mountain district, arose slowly toward its present elevation, the waters gradually receded southward and southwestward, and then more recent beds continued to be accumulated, until this formation spread itself over the vast area which it now occupies. We thus think that, by means of these Cretaceous and Tertiary deposits of the West, we can yet trace step by step the progress of that grand development which has given the present geographical conformation to the West, and originated the fountains from which flow those mighty rivers which may well be called the commercial arteries of the American continent.

Another illustration of the gradual and long-continued rise of the country may be found in the immense chasms or cañons which have been formed by the streams along

*Same as the Wahsatch Group, 1878.
†See this Journal, vol. xxxi, March, 1861.

the mountain sides. We can only account for them on the supposition that as the anticlinal crest was slowly emerging from the sea, the myriad sources of our great rivers were seeking their natural channels, and that these branches or tributaries began this erosive action long before the great thoroughfares, the valleys of the Mississippi and the Missouri, were marked out. The erosion would go on as the mountains continued slowly rising at an almost imperceptible rate, and in process of time the stupendous channels which everywhere meet us along the immediate sides of the mountains would be formed. If we examine the barometrical profiles, already referred to, we see at a glance that in traversing the country from the Mississippi to the foot of the mountains the ascent is very gradual, but increases as we approach the upheaved ridges. In an equal proportion will the rapidity and consequently the erosive power of the streams be increased so that we may readily account for those grand displays of the erosive action of water which occur so frequently along the mountain sides. Eastward from the mountains, beyond this immediate influence, the descent is so gradual that the Missouri flows quietly along over its yielding alluvial bed, transporting its sediments to the Gulf of Mexico.

That the progressive elevation of the country continued up to our present period, or at least until near the time of the deposition of the most recent superficial deposits, we think we have evidence derived from the terraces, which are seen all along the streams. The elevation of these terraces increases as we approach the sources of the rivers, averaging from a few feet to 150 or 200 feet in height. This subject will be discussed more fully in a future article.

We conclude, therefore, that the barometrical profiles, constructed from explorations across our continent, and geological data, indicate a long-continued quiet expansion of the earth's crust, commencing toward the close of the Cretaceous epoch and extending even to our present period; that near the close of the accumulation of the Tertiary lignite deposits, the crust of the earth had reached its utmost tension, the long lines of fractures had commenced, and the anticlinal crests of the mountain ranges were marked out. In a previous paper in this Journal, we remarked that there is no unconformability in any of the fossiliferous sedimentary strata in the Northwest, from the Potsdam sandstone to the summits of the true lignite Tertiary. We believe, therefore, that the elevated ridges which form the nuclei of the mountain ranges began to emerge above the surface of the surrounding country near the close of the Eocene period. We think also that the evidence is clear that there were periods of subsidence and repose; but the thought which we wish to illustrate is, that there was a slow, long-continued, quiet, upward tendency which began near the close of the Cretaceous epoch and culminated in the present configuration of the western portion of our continent near the commencement of our present period.

WASHINGTON, D. C., *January* 1, 1862.

ART. XXXIV.—REMARKS ON THE GEOLOGICAL FORMATIONS ALONG THE EASTERN MARGINS OF THE ROCKY MOUNTAINS.*

BY F. V. HAYDEN.

[From the American Journal of Science, May, 1868.]

On several former occasions I have described the different geological periods represented by the rocks uplifted along the margins of the Rocky Mountains and especially along the eastern slope. Examinations over a great extent of country in considerable detail, from latitude 49° south nearly to the Arkansas River, have shown me that quite marked lithological and paleontological changes occur in them all as we proceed from the north southward. It is the purpose of this article to note this fact somewhat more in detail than hitherto. Beginning with the nucleus of the Rocky Mountains at any point along the eastern range, we find it composed of massive granite rocks, mostly red feldspathic, but not unfrequently gray or other shades of color; then a series of metamorphic rocks (as they are usually called, though no doubt all the granites should be included with them), syenites, diorites, clay, mica, and hornblende slates, and igneous rocks of various kinds here and there.

Proceeding outward, we find the Silurian period represented by the Potsdam sandstone, Devonian wanting, then Carboniferous, Red Beds (Triassic ?), Jurassic, Creta-

* This article refers only to the eastern ranges of the Rocky Mountains, extending south to the Arkansas. The same remarks may or may not apply to other portions.

ceous, and Tertiary, all connected together in the regular order of sequence, and all but the most recent Tertiary in strict conformity. The Tertiary deposits do not exhibit any marked change either in their mineral or fossil contents from the northern portion of our domain to the Arkansas, but the Cretaceous beds present several quite marked changes. Nos.* 5 and 4 maintain their peculiar characters as shown on the Upper Missouri, wherever they are exposed all along the eastern slope, except that they contain comparatively few fossils, yet a few characteristic species are found wherever these beds are seen, which identify them. On the Missouri River, No. 3 attains a great thickness, 400 to 600 feet, presenting massive escarpments of yellow chalk, and it can be traced all the way across the prairie country lying between 98° and 100° longitude. At Forts Hayes and Wallace on the Union Pacific Railway, Eastern Division, there are massive beds of this chalk which is sawed into building blocks with a common saw, and in many instances it is nearly as white as our chalk of commerce and might be used for the same purposes.

The two characteristic species of fossils of this division are found everywhere, *Ostrea congesta* and *Inoceramus problematicus*. All along the slope of the mountains No. 3 still retains its chalky nature, but becomes quite shaly, none of the layers ever becoming more than one or two inches in thickness. This is the case at the sources of the Missouri along the Bighorn and Wind River Mountains also, from the South Pass to Pike's Peak, and on the western slope wherever this bed is exposed. Near Denver, at Marshall's coal-mine, No. 3 has been changed by heat into a grayish compact limestone, quite hard and brittle in its fracture, which makes an excellent flux in smelting ores. But this change is local, for 16 miles north of this point it presents the same laminated character. It seems that No. 3 loses its massive chalky character, by which it first attracted attention on the Missouri River, in its westward extension, so that along the margins of the mountains, except in one locality, it cannot prove of any economical value, while between 98° and 100° longitude it becomes very useful not only for lime, but also for building purposes. No. 2, like Nos. 4 and 5, retains its dark plastic clay character everywhere that it has been observed, but, like the others, it is not nearly as well developed in Colorado as on the Upper Missouri. Near Fort Benton it attains a thickness of 200 to 400 feet, while in Colorado it is not more than 50 to 150 feet. Between longitude 96° and 99° No. 1 retains its deep rust-red sandy characters with dicotyledonous leaves from the Missouri River to the Arkansas, but nowhere along the margins of the mountains from latitude 49° to Pike's Peak have I ever seen any well-defined palæontological proof of its existence. Near Fort Benton are a series of Cretaceous beds containing some seams of impure lignite and numerous species of fossils, not one of which is identical with those so abundant in Nos. 4 and 5 lower down on the Missouri. These beds have been placed provisionally in the general section as a portion of No. 1, but the region about Fort Benton needs a more careful examination before any positive conclusions can be arrived at. Around the Black Hills is a bed of massive siliceous rocks, some layers forming a pudding stone, which in some localities takes the name of fortification rocks. These hold a position between No. 2 Cretaceous and the Jurassic marls. The same are seen along the margin of the Bighorn Mountains, in which I observed a bed of impure lignite, an abundance of silicified wood, and some uncharacteristic Saurian bones. From the Wind River Mountains to Pike's Peak these same siliceous and pebble cemented rocks occur holding the same geological position, forming, as it were, beds of transition between the Cretaceous and the Jurassic periods. I have carefully examined these rocks for hundreds of miles and have never yet detected any organic remains, animal or vegetable, in them.

The Jurassic beds, as revealed along the mountains, possess peculiar and marked lithological characters, so that having identified them by the fossils in one locality we can trace them over great areas. They were first shown to exist in the West in the form of a zone engirdling the Black Hills. They here attain a thickness from 200 to 300 feet at least, and from the beds in this locality alone have fossils enough been collected of such unmistakable Jurassic types as to prove their existence beyond a doubt. But these beds have also been shown, since they were first made known in the Black Hills, to be exposed along the margins of the Bighorn and Wind River Mountains near Red Buttes, on North Platte, and in numerous localities in the Laramie Plains, and westward to Fort Bridger. So numerous are the species now known from the West and so close are the affinities of most of them to well-known Jurassic types that it is not necessary for me in this place to detail the evidence in support of that statement.

It is sufficient to remark that the Jurassic system is quite plainly represented along the margins of the different ranges of mountains north of latitude 42°, but proceeding southward from Deer Creek on the North Platte, the Jurassic beds diminish in force until near Cache la Poudre it becomes doubtful whether they are represented at all'

* The different divisions of the Cretaceous period, as shown on the Missouri River, have received geographical names, as Fort Benton Group, &c., but I use the old divisions by figures for brevity.

At this point there is a thin bed, perhaps 20 to 50 feet in thickness, of greenish-gray arenaceous marl overlying the Red Beds, which seem to occupy the place of the Jurassic. This seems to thin out more and more as we proceed southward toward the Arkansas. From Deer Creek 100 miles north of Fort Laramie to Denver, a distance of 400 miles, I have searched in vain for any organic remains in the rocks which appear to represent the Jurassic period of the Black Hills, Bighorn and Wind River Mountains. In the Red Beds or supposed Triassic no organic remains have been found north of the Arkansas, and they do not differ much lithologically in their southward extension, except that they seem to be much thicker and more gypsiferous northward. In the far north the Carboniferous rocks are in many localities 500 to 1,500 feet in thickness, and even as far south as the Red Buttes the massive beds of limestone, with true Carboniferous fossils, are exposed 500 to 1,000 feet thick, and are quite distinct from the red or variegated beds. But as we proceed southward from this point the Carboniferous limestones seem to lose their usual lithological characters and the Red Beds prevail. At the head of Pole Creek on the eastern margin and in the Laramie Plains west, the Carboniferous rocks are mostly of a red arenaceous character, with a few layers 2 to 10 feet in thickness of whitish or yellowish limestone. From these limestones I collected *Productus Prattenianus*, *Athyris subtilita*, and other well-known Carboniferous forms.

Above these Red Beds, which contain intercalated layers of limestone, is a considerable thickness of purely red arenaceous beds, but in studying all these rocks with some care from Pole Creek nearly to Pike's Peak, I could not separate the Red Beds from the Carboniferous by any break in continuity, and I was rather inclined to the opinion that inasmuch as a large portion of the gypsiferous or variegated beds could be shown to be Carboniferous, they might possibly all be included in that period. The Potsdam sandstone, the only portion of the Silurian era ever detected along the eastern slope of the Rocky Mountains north of the Arkansas, seems to fade out entirely south of the Red Buttes on the North Platte. It is well defined around the Black Hills, Bighorn, and Wind River Mountains. Near the Red Buttes there is a bed of siliceous pudding stone resting on the metamorphic rocks which may be the Potsdam in its southern extension, but south of Fort Laramie to Pike's Peak it is somewhat doubtful whether any trace of it exists. If it occurs at all it a very thin layer, for the most part concealed. So far as I could determine, the Carboniferous rocks rest directly (though not conforming) upon the metamorphic rocks. There is also some change in the nuclei of the mountain ranges southward. At the north the feldspathic and the gray granites prevail, but southward the syenites and igneous rocks form the central portions of the mountains almost entirely. It is rare to see true granite.

The above remarks, founded on observations that have been made over a very great extent of country through a period of many years, lead me to the following conclusions:

1st. That all the formations of the West undergo more or less change both in their mineral and fossil contents in their extension toward the west and south. They all seem to reach their culmination not far from the central portion of the great area drained by the Missouri, and lose to a great extent their distinctive characters beyond its limits.

2d. The Potsdam sandstone and the Jurassic beds present more remarkable changes than any of the others. While north both these formations are well marked, both lithologically and palæontologically in their southward extension they gradually fade out, so that south of Fort Laramie to Pike's Peak it becomes a matter of doubt whether they exist at all. The inference therefore is that these groups of rocks are not well defined, if they occur at all south of the Arkansas. In support of this statement is the fact that although this southern region has been traversed in every direction by multitudes of explorers for thirty years past, among whom have been geologists of high reputation, yet south of latitude 40° not a single animal fossil has ever been detected with Jurassic affinities, and it is quite doubtful whether any have been found with Triassic or Permian relations;* even the few plants that have been found are doubtful in their affinities and are regarded as probably Cretaceous or Permian. I have made these remarks from the fact that all the observations that have been made by explorers in the West during the past will, ere many years, be put to the rigid test of a most careful scrutiny, and an error by whomsoever made, though sustained by the highest authority in the land, will fall to the ground before the light of true science as the dead bark from a tree. The ease with which the Rocky Mountain region can soon be reached, in a few years, when our great national highways are completed to the Pacific, will induce the best geologists in this country and in Europe to visit them, and the many intricate problems of Rocky Mountain geology must be solved.

* I do not wish to be understood as saying that the Jurassic rocks do not occur, south of the Arkansas, as well as the Permian and Triassic, for there is ample room for their fullest development, but no evidence has ever yet been obtained of its (Jurassic) existence, although the country has been so long traversed by explorers. The evidence, so far as it goes, would seem to be against its occurrence at all.

The great school of mines, which will no doubt be soon established in the heart of the mining districts of the Rocky Mountains, must gather around it able men who will either sustain or reject the observations of other investigators who have examined the country under less favorable auspices.

THE PRIMORDIAL SANDSTONE OF THE ROCKY MOUNTAINS IN THE NORTHWESTERN TERRITORIES ON THE UNITED STATES.

By Dr. F. V. Hayden.

[From the American Journal of Science and Arts, vol. xxxiii, Jan., 1862.]

We have attempted in this paper to present as clear and connected an account as the known facts will permit, of the Primordial rocks west of the Mississippi, more especially those of the northwest, west of longitude 96°. The Potsdam sandstone of the New York series is the division of the Primordial zone of Barrande, mainly represented in the Rocky Mountain district, and is that part alluded to unless otherwise mentioned.

In speaking of the geographical distribution of the Potsdam sandstone reference will be made to localities to the eastward where it has furnished most abundant and satisfactory testimony in regard to its age. We will, in the first place, present more in detail such facts as we have been able to obtain by personal observation in the field, and by the aid of these and the statements of reliable explorers we hope to give some idea of the geographical extension of this wide-spread formation in the West.

Our first knowledge of Primordial rocks west of the Missouri River was obtained in the summer of 1857, during the exploration of the Black Hills of Nebraska, by an expedition under the command of Lieut. G. K. Warren, Topographical Engineers. The more important facts, with the determination of the fossils, were published by Mr. Meek and the writer in March, 1858.*

By reference to the general map of the country west of the Mississippi, recently published under the auspices of the War Department, we find that the Black Hills lie between the 43d and 45th degrees of latitude, and the 103d and 104th degrees of longitude, and occupy an area about 80 miles in length, and from 30 to 50 in width. According to Lieutenant Warren the shape of the mass is elliptical and the major axis trends about 20° west of north. The base of these hills is about 2,500 to 3,000 feet, and the highest peaks 6,700 feet above the ocean. The entire range is clasped, as it were, by the North and South Branches of the Shyenne River, the most inportant stream in this region. The North Branch passes along the north side of the range, receiving most of its waters from it, but taking its rise far to the westward near the sources of Powder River, in the "divide," between the waters of the Yellowstone and those of the Missouri. The South Branch also rises in the same "divide," flows along the southern base of this range, receiving the waters of numerous tributaries which have their sources in it.

Again, by referring to the map above alluded to, we ascertain that the Black Hills form the most eastern outlier of the great Rocky Mountain Range as well as the first point where rocks older than the Carboniferous are exposed to the eye after leaving the Missouri westward. These hills would seem to constitute an independent elevation, so far are they removed from other ranges, were it not for a low anticlinal which may be traced across the plain country southward, connecting them with the Laramie Mountains near Laramie Peak. The central portion is composed of red feldspathic granite and stratified Azoic rocks, and resting unconformably upon, and forming a zone or belt around the ellipsoidal nucleus, are a series of variable, reddish ferruginous sandstones, which by their organic remains furnish the most reliable evidence that they belong to the Potsdam period.

As observed in and around the Black Hills, the Potsdam sandstone presents a great variety of lithological characters. In many localities it is composed of a conglomerate of more or less water-worn pebbles, mostly whitish crystalline quartz, but representing to a greater or less extent the different varieties of the changed rocks beneath. The pebbles vary in size from an eighth of an inch to four inches in diameter cemented together with a silico-calcareous paste. Some of the pebbles are scarcely worn, while others are quite smooth. At the locality where the following section was taken, the sandstone is of a gray color tinged with red at the base, but ascending it becomes more

* Proceedings of the Academy Nat. Sci., Pa., March, 1858.

ferruginous until its color is a dark dull red, and its texture a coarse-grained friable sandstone with many quartzose and micaceous particles and some calcareous matter. Seams two to four inches in thickness are very nearly composed of shells of the genera *Lingula*, *Obolella*, &c., which, though quite fragile in their nature, are so well preserved as to be easily identified. The following section taken near the central portion of the Black Hills exhibits Carboniferous rocks and the Potsdam sandstone conforming to each other, but the latter resting discordantly upon the Azoic stratified and granitic rocks.

	Feet.
1. A hard, compact, fine-grained yellowish limestone of an excellent quality, passing down into a yellow calcareous sandstone, quite friable. Fossils: *Spirifer Rockymontana*, Marcou; an *Athyris*, like *A. subtilita*, *Cyptoceras*, &c......	50
2. Loose layers of very hard yellow arenaceous limestone with a reddish tinge, underlaid by a bed, six to eight feet in thickness, of very hard blue limestone; the whole contains great quantities of broken crinoidal remains with cyathophylloid corals and several species of brachiopoda....................	40
3. Variegated sandstone, of a gray and ferruginous red color, composed chiefly of grains of quartz and particles of mica cemented with calcareous matter. Some portions of the bed are very hard, compact, siliceous; others a coarse friable grit; others a conglomerate. Fossils: *Lingula prima*, *L. antiqua*, *Obolella nana*, and fragments of a trilobite, *Arionellus? Oweni*................	50 to 80
4. Stratified Azoic rocks standing in a vertical position for the most part.	

Leaving the Black Hills in a direction a little west of south, we follow an anticlinal valley to the Laramie Mountains with which the Black Hills seem thus obscurely connected. The evidence, so far as it goes, appears to indicate that the same force which elevated the one raised the other, and that the events were synchronous. We do not observe the lower rocks after leaving the Black Hills until we reach the source of the Niobrara River, where we find a series of horizontal strata resting upon the vertical edges of Azoic clay slates and schists, which from their lithological characters and position doubtless belong to the age of the Potsdam sandstone, though no organic remains could be found. The following section shows the descending order of the beds.

	Feet.
1. Quartzose sandstone, some parts filled with pebbles	22
2. Red argillaceous slate..	5
3. Sandstone, dull reddish ferruginous, like bed 1, above	37
4. A series of strata more or less inclined, composed of gneiss with silvery mica in large plates, micaceous and talcose slates, white quartz, &c.	

We have no doubt that the Potsdam sandstone occurs in the form of an outcropping belt all along the Laramie range of mountains, though, after a thorough search we were unable to discover any organic remains. Having once fixed the position and age of a formation, as the Potsdam sandstone is established in the Black Hills, we may rely with considerable confidence upon the physical characters and stratigraphical position to determine the age of rocks in the same district of country. We have on these grounds regarded certain rocks along the Laramie Range as of this age. In the first ridge of elevation west of the trading post on La Prele Creek, about 60 miles northwest of Fort Laramie, is a series of rocky layers 50 feet in thickness, reposing unconformably upon red feldspathic granites, mica schists, and clay slates. The lower portion is a fine-grained subcrystalline quartzose rock, partially metamorphosed, passing up into a friable sandstone arranged in thin layers, with the laminæ quite oblique, overlaid by a considerable thickness of conglomerate. The dip is about 20° east. Resting upon these supposed Potsdam rocks at this point and inclining at about the same angle are layers of limestone, containing numerous fossils which prove them to belong to the Carboniferous age.

Again, further southward along the same range, near the source of the Chugwater River we find the same limestones well developed, containing some Carboniferous fossils, and underneath them and inclining in the same direction is a group of strata of a brick-red color, more or less changed by heat, holding the position of the Potsdam sandstone in other localities. In some places these rocks are so metamorphosed by heat from beneath as to appear like a red feldspathic granite, and in others, like a reddened granular sandstone containing numerous unchanged masses of quartz.

At the Shyenne Pass, we observed the well-known Carboniferous rocks, inclining about 13°. Beneath them is a considerable thickness of red marls and laminated sandstone, and still farther down and inclining 26° is a quartzose sandstone, full of water-worn pebbles, passing down into layers which at a distance look like indurated clay, but which, on closer examination, proved to be an aggregation of quartz and feldspar crystals cemented with a calcareous paste. At another locality we have the following characters: (1) a grayish quartzose sandstone, 12 inches; then descending, (2) laminated granitoid rock, 2 feet; (3) compact reddish ferruginous granitoid material, 8 feet; (4) a considerable thickness, perhaps 50 feet, of feldspar crystals cemented with a calcareous paste, inclining 13°. Though we could find no organic remains in these supposed Potsdam rocks along the Laramie range of mountains, yet their stratigraphical position and physical characters leave very little room for doubt as to their age.

Although we think that the known facts justify the inference that the Potsdam sandstone is revealed in an outcropping belt all along the margins of the Bighorn Range, resting unconformably upon the Azoic rocks beneath, yet we were unable to make a careful examination except in a few localities. We could see, however, in the loose material scattered along the foot of the mountains, washed down by the streams, masses of sandstone closely resembling the rock under consideration. Near the source of Powder River we penetrated to the nucleus of the mountains and found a series of sandstones underlying the Carboniferous limestone and resting unconformably upon the schistose and clay slates of the Azoic series, in very nearly the same manner as in the Black Hills before described. The Potsdam sandstone in this region is quite well developed, attaining a thickness of 200 feet, and exhibiting its usual variable lithological characters. Near the base, the rock is of a reddish flesh-color, very compact, composed of an aggregation of quartz pebbles, varying in size from a minute grain of quartz to masses half an inch in diameter, cemented with siliceous matter. Portions of the rock contain many pebbles of jasper which appear to have been slightly worn before being inclosed in the calcareous paste. Passing up we find the rock to be arranged in thin ferruginous layers, slightly calcareous but mostly siliceous, with many small particles of mica. These thin layers are also charged with fossils, as *Lingula antiqua*, *Obolella nana*, *Theca gregarea*, and *Arionellus? Oweni*. Many of the slabs were covered with fucoidal markings and what appear to be tracks or trails of worms. The upper part of this formation as seen in the Bighorn Mountains is a rust-color granular sandstone, the small siliceous grains being held together by a calcareous cement which causes the rock to effervesce briskly on the application of an acid. In tracing the different fossiliferous rocks, at this locality, from the nucleus outward, we can see a good illustration of the strict conformability of all the formations from the Potsdam sandstone to the summit of the Lignite Tertiary. We see here the evidences of only two great periods of disturbance, the one occurring prior to the deposition of the Primordial sandstones which inclined the Azoic rocks, and the other at the close of the accumulation of the true Lignite Tertiary deposits when the mountain nuclei began their elevation above the surrounding country.

Along the Wind River Mountains, which extend far northward and form the dividing crest of the great Rocky Range, the Potsdam sandstone is quite thinly represented and yielded no organic remains to a somewhat hasty examination. Near the junction of the three forks of the Missouri, alternate strata of clay, limestone, and compact siliceous rock occur beneath well-marked Carboniferous beds. These rocks are evidently of ancient date, and were deposited in quite shallow water, as is shown by numerous thin layers of rock covered with trails of worms and fucoidal plants. These facts thus enumerated would seem to indicate with considerable certainty that this rock once spread over the area occupied by the central range of the Rocky Mountains, doubtless extending far north beyond the limits of the territories of the United States. The predominance of eruptive rocks as we pass northward along the main range of the Rocky Mountains greatly increases the difficulty in tracing out the lower fossiliferous beds.

We have now described this member of the Primordial zone as far as it has occurred within the limits of our own observations. It now becomes an interesting point to determine its geographical extension in the West, and for that purpose we propose to summon all the evidence at our command. The proof will not, however, be as satisfactory as could be desired, owing to the general absence of organic remains.

If we now extend our examinations far north into the Hudson's Bay territory, we find that much interesting information has been obtained in regard to the Silurian rocks of that region, but not accompanied by the evidence which gives to the knowledge acquired that definiteness which is desirable. It is probable, however, that when not eroded away or concealed by more recent deposits, the Potsdam sandstone and, perhaps, rocks of more recent Silurian age occur all along the margins of the Rocky Mountains to the Arctic Sea. To what extent still more recent or Upper Silurian occur over this vast region our present knowledge will not enable us to determine, but the few fossils which have been collected indicate that the great Silurian Sea extended over much of the Northwest. Sir John Richardson mentions the existence of conglomerates and sandstones to which succeed limestones and clay slates, probably of Silurian age, and granite. We know that in many localities in the mountains, about the sources of the Missouri, the rocks of the Potsdam period are composed of sandstones and more or less coarse conglomerates. Underneath are clay slates and very hard limestones of Azoic age, and to these succeed granite. As we proceed northward the evidence of true Lower Silurian rocks gives place to those of Upper Silurian age, which have furnished a good supply of organic remains. According to Mr. Isbister, these rocks are well developed around Hudson's Bay, Great Slave Lake and River, Lake Winnipeg, &c. He cites numerous fossils as belonging to Silurian types, but the species are too numerous to mention here. We may simply state that, so far as our knowledge extends, there is no evidence which renders it certain that any portion of the Primordial zone of of Barande occurs north of latitude 49°, though it is quite probable that when carefully sought after it will be found revealed along the margins of the mountain elevations to the Arctic Sea.

As we proceed southward along the line of the mountain ranges toward New Mexico, though no fossils have been found, we feel safe, acting upon our previous knowledge, in regarding the evidence as quite clear that this sandstone occurs in numerous localities. In our investigations of the geology of the West, we have relied on three tests of evidence, viz:

First. Palæontological evidence, which is the most important and in most instances the only conclusive proof.

Second. Stratigraphical position.

Third. Lithological resemblance.

The last two tests are all we have to rely upon to determine the extension of the Lower Silurian rocks as we proceed southward from the Black Hills. Having traced rocks which we regard of this age south to a point on a parallel with the Salt Lake district, we present the following resemblances in lithological characters as probable evidence of their existence in Utah Territory:

Professor Hall, in Stansbury's report, in several places describes a bed of sandstone corresponding in its lithological characters and geological position to the Potsdam sandstone in the Black Hills. Stansbury Island (Great Salt Lake), the summit of which is 3,000 feet in height, is capped with Carboniferous limestones, which rest upon a coarse sandstone or conglomerate. Again, north of Great Salt Lake City the limestone overlies a coarse sandstone or conglomerate, which almost invariably accompanies it. In several localities, as at Promontory Point and near Mud Island, the metamorphic strata appear to be overlaid by a coarse conglomerate or coarse sandstone, which is partially altered and assumes the character of a quartz rock. Marcou, in the third volume of Pacific Railroad reports, page 156, mentions a formation occurring near the Aztec Mountains. He says: "We traveled seven miles upon the granite, then a bed of red sandstone; above this the beds of limestone and gray sandstone belonging to the mountain limestone." The following day "we traveled three miles on the granite, the remainder on the Old Red Sandstone." An excellent diagram, illustrating a section of the rocks near the mountains above alluded to, accompanies Mr. Marcou's remarks, which would apply equally well to similar beds in the Black Hills. The great uniformity in the physical characters of the different formations over large areas, which have been examined with care and definite knowledge obtained, leads us to place some degree of confidence in the above statements. From latitude 49° to 40° south, and east of the dividing crest, we have the Potsdam sandstone, then, immediately above it, with remarkable uniformity, a series of beds of limestones containing true Carboniferous fossils. We infer, therefore, that both northward and southward the same uniformity of geological structure continued, unless we have evidence to the contrary.

The observations of Dr. J. S. Newberry render it quite probable that rocks of Lower Silurian age occur along the valley of the Colorado. The following paragraphs from a letter addressed to the writer by Dr. Newberry are extracted by permission:

"I have never collected any unmistakable Silurian fossils in the far West. I am perfectly satisfied that the lower stratified rocks of the Colorado section are Silurian, but the only fossils they contain are too much changed to be satisfactorily identified.

"The lower rocks above the granite are coarse, red sandstones, lithologically and stratigraphically corresponding to your Potsdam of the Black Hills; above these a great thickness, over 300 feet, of shales, limestones, and sandstones, and then the first Carboniferous fossils.

"Just above the Potsdam (?) is a limestone filled with corals, apparently *Chætetes lycoperdon*, or rather the same with that so common in the Trenton, with branching stems, formerly included in *C. lycoperdon*, but evidently distinct. On the mountains bounding the Colorado basin the Carboniferous rocks rest directly upon the granite."

We have now considered the Potsdam sandstone in its geographical extension over the West as far as we are acquainted with its existence, and have pointed out the localities where it is revealed. Along the Mississippi Valley and eastward most important discoveries are made annually, which show it to be developed everywhere when the conditions are favorable for its exhibition. It is true that in some localities beds of more recent age repose directly upon Azoic rocks, but in these cases may not the Primordial sandstones lie concealed or be eroded away? The researches of Dr. B. F. Shumard in Texas have shown that the Primordial zone attains a considerable thickness in the Southwest, and is charged with an interesting group of its peculiar fossil forms. The examination of others proved its existence all along the Atlantic coast extending westward from Canada to Wisconsin, Iowa, and Minnesota, and thus a great period in the world's geological history, formerly supposed to possess but a meager fauna, the first representatives of life on our globe, has already yielded very abundant and varied forms. The following is a summary of the principal facts and conclusions from our knowledge of the Potsdam sandstone in the far West:

1. We have the most undoubted evidence of the existence of that division of the Primordial zone, which is the equivalent of the Potsdam sandstone of the New York series in two important ranges of mountains, outliers of the great Rocky Mountain chain. All the fossils are well known Primordial types, and at least two species are identical with forms occurring at the typical localities of this period in the Eastern States. The others are forms closely allied to species found in the equivalent rocks both in this country and in Europe.

2. This division of the Primordial zone, as a rule, appears as an underlying formation, when the conditions are such as to expose it to view, from the Atlantic coast to the crest of the Rocky Mountains, and probably farther. Localities doubtless do occur where rocks of more recent age than the Potsdam sandstone rest directly upon the Azoic or granitic rocks below; but these facts to not militate against the general rule. Having proved its existence in two important ranges of mountains from its organic remains, by means of lithological resemblance and stratigraphical position, we have with considerable confidence traced it by personal observations throughout the mountainous district comprised within latitude 40° and 49° and longitude 103° and 112°. From these facts and the observations of reliable explorers in different parts of the West, we we think we are warranted in the belief that this rock is exposed all along the margins of the Rocky Mountain Range when not eroded away or concealed by overlying formations. How far westward of the dividing crest of the Rocky Mountains it extended we have no data for determining, nor can we hope to have, where eruptive rocks seem to predominate. As yet we have not known the Potsdam sandstone to be exposed, except along mountains with a true granite nucleus.

3. Wherever this rock occurs, we are struck not only with the peculiarity of the organic remains, but also with the remarkable uniformity in the nature of the sediments and the general lithological appearance, compared with its equivalents in more eastern localities. We do not believe this to be due to currents of water bearing the materials from far eastern lands, but that the sediments were obtained from the vicinity, and that the uniformity in their character arises from the nature of the underlying rocks from which they were derived.

The Potsdam sandstone is everywhere composed of calcareous and silicious matter, granular quartz, ferruginous material in great quantities, also pebbles of various kinds worn and unworn, with now and then seams and layers of argillaceous material. We find in the Azoic rocks below an abundance of limestone, clay slates, mica schists, seams of white quartz, granite composed largely of feldspar, and we can readily detect the source of the fragmentary masses which form the conglomerates. We also know that while nuclei of certain mountain ranges on the eastern slope are composed of a massive feldspathic granite, a great thickness of more recent or overlying rock, forming the lower and smaller ridges, are composed of a kind of "rotten granite," which is so full of the hydrated oxide of iron that it readily decomposes on exposure to the atmosphere. We therefore believe that the source of all the sediments composing the Primordial rocks in the West can be traced to the underlying rocks in the vicinity.

4. There are no indications of long-continued deep water in the Primordial sea, so far as the West is concerned. If we examine the lower part of the Potsdam sandstone, we find that the physical conditions which ushered in this period were quite violent, as is shown by the conglomerate character of the rock. Passing upward, this conglomerate graduates into a rock composed of granules of quartz and small plates of mica cemented with calcareous matter, and about midway in the formation we have a fine, very ferruginous calcareous sandstone, in thin layers, filled with fossils in a very good state of preservation. The condition of the organic remains, the fineness of the sediment, and the perfect horizontality of the laminæ of deposition indicate a short period at least of quiet water. As we continue upward the rocks begin to show the shifting nature of the currents, shallow water and perhaps a proximity to land, by oblique laminæ of deposit, ripple markings, and fucoidal remains. The upper portion of this rock contains no fossils, nor were the physical conditions such as to have preserved them even if they had existed.

5. There seem to be evidences of a gradual thining out of the Primordial sandstone in its far western extension, as also of all the Palæozoic formations. According to Dr. Owen, the Protozoic sandstones in Minnesota are at least 500 to 600 feet in thickness, and in Iowa Professor Whitney estimates them at from 250 to 400 feet. In Tennessee Professor Safford finds several thousand feet of rocks, which he refers to this age; and in Texas, where they seem to be quite well exhibited and to yield a large number of fossils, Dr. Shumard gives them as only about 500 feet. In the Rocky Mountain district they are seldom more than 80 feet and never over 200 feet. Indeed, all the Primary fossiliferous rocks are but thinly represented there, while the lower Secondary formations begin gradually to increase in force until all along the eastern

slope we have an enormous development of the Upper Secondary and Tertiary, with an aggregate thickness of from 8,000 to 10,000 feet.

6. So far as we yet know, there is no unconformability in any of the fossiliferous sedimentary rocks of the Northwest from the Potsdam sandstone to the summits of the true Lignite Tertiary. There are proofs of two great periods of disturbance which had a marked influence upon the physical geography of the West. The one occurred prior to the deposition of the Potsdam sandstone, when the Azoic or granitic rocks were elevated into a more or less inclined position, and the other and most important period took place at the close of the accumulation of the great Lignite Tertiary deposits, when the great lines of fracture were produced and the massive nuclei of the mountain ranges wete raised above the surrounding country.

7. What changes took place in the physical geography of the West during the long period which must have elapsed after the deposition of the Potsdam sandstone until the commencement of the Carboniferous age, we have very few data to determine. We are inclined to think that this portion of the West at least was elevated above the water level during the greater part of that period; the numerous indications of shallow water during the accumulation of the Potsdam sandstone and the almost entire absence of rocks of intermediate age over so large an area further strengthens that opinion. It is true that in the far Northwest we have proofs that the hiatus is partially filled, but in the South and Southwest the evidence is still more meager. Near the Humboldt Mountains, in Utah, Messrs. Meek and Engelmann have detected proofs of Devonian rocks, but they are not known to be largely developed, and on the western declivity of the El Paso Mountains Dr. G. Shumard found "well-marked strata of the inferior Silurian system corresponding in age to the Blue Limestone of Cincinnati and the Hudson River Group of the New York series."* But so far as our present knowledge extends, rocks of intermediate ages do not form a prominent feature in the geology of the West.

WASHINGTON, *November*, 1861.

SKETCH OF THE GEOLOGY OF THE COUNTRY ABOUT THE HEAD-WATERS OF THE MISSOURI AND YELLOWSTONE RIVERS

By Dr. F. V. HAYDEN.

[From the American Journal of Science and Arts, vol. xxxi, March, 1861.]

The observations made during the recent expedition to the headwaters of the Missouri and Yellowstone Rivers, under the command of Capt. William F. Raynolds, Topographical Engineers, have served to extend quite largely our knowledge of the geographical area of the different geological formations already indicated as existing in the far West. I propose in the following paper to present a brief abstract of the leading facts ascertained with a view to their bearing upon the physical geology of the mountain chains. I know that it will be impossible within the limits of a single paper to make every point as clear as could be desired, or to use terms in all cases in their usually restricted sense. Much of the country passed over, west of the Black Hills, had never before been explored by scientific men, no maps existed which exhibited its topography with any pretensions to accuracy, and the mountain ranges which were known to exist in that region from information given by traders and trappers were not always laid down in their true geographical localities or with their proper trend; and not until the forthcoming report of Captain Raynolds, now in course of preparation, appears can these deficiencies be supplied. Moreover, the wild and broken character of the surface of the country examined, uninhabited except by roving tribes of hostile Indians, precluded the possibility of perfect accuracy in all the minor details, and we can only hope that we have obtained a general idea of the principal geological features of the vast area explored. The rocks observed belong to the different geological periods in the following order:

I. Granite, stratified Azoic, and eruptive rocks.†

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*Transactions of the Academy of Sciences, Saint Louis, vol. i, No. 2, page 288.

†By granite or granitoid I mean those unstratified crystalline rocks in the West which hold a lower position than any of the stratified deposits and for the most part possess a uniform character, forming the central portions of the larger mountains; by stratified Azoic, a series of non-fossiliferous stratified beds, apparently sedimentary between the granite and Potsdam sandstone, and by eruptive rocks, those which have been melted by volcanic heat and brought to the surface in a more or less fluid condition, at various periods.

II. Potsdam sandstone (Silurian).
III. Carboniferous rocks (including Permian ?).
IV. Red arenaceous deposits.
V. Jurassic beds.
VI. Cretaceous, with its divisions.
VII. Tertiary deposits.

I.—GRANITE, STRATIFIED AZOIC, AND ERUPTIVE ROCKS.

Under the first division of my subject I will take up the mountain elevations as they appeared in their detached portions along our route. It is now well known that the term "Rocky Mountains" is quite general in its application, including a vast number of more or less important ranges of mountains, which, when examined in detail, seem to have been elevated with very little regularity and in many instances to be but slightly connected, but when viewed in the aggregate to present a trend nearly northwest and southeast. Before reaching the main range we find along the eastern slope many detached minor elevations showing the wide geographical area under which the elevating forces acted.

I allude in the first place to the Black Hills, the northern portion of which we examined on our route from Fort Pierre, on the Missouri, to the Yellowstone River. These hills form the most eastern outlier of the Rocky Mountains, and would seem to be an independent elevation were it not for a low anticlinal which extends across the plain country southward, connecting it with the Laramie Mountains. The central portion is composed of a coarse flesh-colored feldspathic granite, with a series of metamorphic slates and schists superimposed, and thence, upon each side of the axis of elevation, the various fossiliferous formations of this region follow in their order to the summits of the Cretaceous, the whole being more or less inclined against the granitic rocks. The distance across the granitoid nucleus is from 15 to 30 miles, and on each side of the crest or axis of elevation we find the corresponding portions of the fossiliferous beds from the Silurian to the summit of the Cretaceous. The evidence therefore is conclusive that all the unchanged sedimentary strata at a period of comparatively recent date extended continuously over the whole area occupied by the Black Hills. The eruptive rocks reveal themselves at various localities, as at Bear Peak, Inyankara Peak, &c. Bear Peak is a protrusion of very compact igneous rocks, almost isolated from the main range of the Black Hills, and Inyankara Peak is for the most part composed of pentagonal basaltic columns arranged in a vertical position. There is no evidence, however, that they were formed by any force independent of that which elevated the entire range of mountains.

The next range that we examined was the Big Horn, which is perhaps the most important detached outlier on the eastern side of the main crest of the continent. This seems to trend nearly northwest and southeast, extending into the valley of the Yellowstone. The nucleus of these mountains is also composed of red feldspathic granite, with a series of stratified Azoic rocks; and the unchanged sedimentary strata to the summit of the Cretaceous and including a portion of the Lignite Tertiary can be seen in regular sequence outward inclining at greater or less angles. From the observations of Dr. C. M. Hines, who acted as geologist to the exploring division under Lieutenant Maynadier, we know that the corresponding formations occur on the opposite side of the axis of elevation, and, as we remarked of the Black Hills, we may infer from this fact that the unchanged sedimentary beds once extended continuously over the whole area occupied by the Big Horn Mountains, in a nearly horizontal position, some time during the Tertiary period. As we pass along the northeastern base of the Big Horn Mountains southwestward, the ridges of upheaval seem to be presented *en echelon*, the range gradually making a flexure around to the westward. Toward the headwaters of Wind River this range, as it attaches itself to the main chain of the mountains, changes its lithological characters, no true ancient granitic rocks being seen, but instead, lofty peaks composed of eruptive rocks, presenting every variety of structure, from compact basalt to porous lava-like masses.

The Laramie Mountains, by which we mean the whole range from the Red Buttes to the Arkansas, were examined with some care from Red Buttes southward nearly to Pike's Peak. There is a remarkable similarity in the general geological features of all the mountains on the eastern slope. The more lofty elevations, as Long's and Pike's Peaks, with other ridges and peaks scarcely less lofty than those just mentioned, are composed of the same coarse feldspathic granite before alluded to, but the lower ridges are formed to a great extent of a ferruginous feldspathic granite which easily yields to atmospheric agencies, and the surface of the country is paved with crystals of feldspar in consequence of its decomposition. All along the base, and often extending up to the crest of the mountains, we see the outcropping edges of the fossiliferous rocks inclining at greater or less angles, and on crossing over into the Laramie Plains we find the corresponding strata leaning from the opposite side. The granitoid nucleus varies from 8 to 20 miles in width. No indications of true eruptive rocks were observed in this range. The Medicine Bow and Sweet Water Mountains appear to be of the same character for the most part, but on the east side of the Sweet Water River the evidence of igneous action is shown on a large scale. The ancient volcanic material would seem to have been elevated to a great height in but a partially fluid condition and then to have gradually cooled, affecting to a greater or less extent the fossiliferous strata in contact.

Near the junction of the Popo Agie with Wind River we came in full view of the Wind River Mountains, which form the dividing crest of the continent, the streams on the one side flowing into the Atlantic and those on the other into the Pacific. This range is also composed to a large extent of red and gray feldspathic granite, with the fossiliferous rocks inclining high upon its sides. After passing the sources of Wind River the mountains appear to be composed entirely of eruptive rocks. Even the Three Tetons, which raise their summits 11,000 feet above the ocean level, are formed of very compact basaltic rock.* The Wasatch and Green River Ranges, where we observed them, have the same igneous origin, and the mountains all along the sources of the different branches of the Columbia exhibit these rocks in their full force. In Pierre's Hole, Jackson's Hole, and other valleys surrounded by upheaved ridges, these ancient volcanic rocks seem to have been poured out over the country and to have cooled in layers, giving to vast thicknesses of the rocks the appearance of stratified beds.

The mountains about the sources of the Missouri and Yellowstone Rivers are of eruptive origin, and in the valley of the Madison Fork of the Missouri are vertical walls of these ancient volcanic rocks 1,000 to 1,500 feet in height, exhibiting the appearance of regularly stratified deposits, dipping at a considerable angle. As we pass down the Madison we find some beds of feldspathic rocks and mica and clay slates beneath the eruptive layers, dipping at the same angle. After passing the divide below the three forks of the Missouri we see a number of partially detached ranges which appear to be of the same igneous character. In the Belt and Highwood Mountains, and indeed all along the eastern slope in this region, we find continual evidence of the outpouring of the fluid material in the form of surface beds, or in layers thrust between the fossiliferous strata. These igneous beds thin out rapidly as we recede from the point of effusion. A large number of these centers of protrusion may be seen along the slope of the mountains west of the Judith Range. The erupted material sometimes presents a vertical wall 300 feet high, then suddenly thins out and disappears. The Judith, Bear's Paw, and Little Rocky Mountains seemed to be composed for the most part of granite and other rocks, with igneous protrusions here and there. I have in a former paper expressed the opinion that the central portions of our mountain ranges are composed of feldspathic granite, and to a certain extent this is true in regard to the more eastern outliers, but more recent observations have convinced me that these rocks which I have defined by the term "eruptive" compose by far the greater portion of the mountain masses of the West.

II.—POTSDAM SANDSTONE (SILURIAN).

The discovery of this formation in its western extension has already been announced in a former paper.† It was first made known as occurring in the Black Hills and resting upon the upturned or nearly vertical edges of the schists, clay slates, and granitoid rocks, and the inference was drawn that the same rocks would be found forming an outcropping belt along the eastern slope of the Rocky Mountains. After leaving the Black Hills we next observed it along the margins of the Big Horn Range near the summit, holding the same relative position and exhibiting the same lithological characters. A few thin layers of fine calcareous sandstone were observed filled with fossils characteristic of this period. At the head of La Bonte Creek, in the Laramie Range, I noticed a bed resting discordantly upon Azoic slates, 50 to 100 feet in thickness, holding the same position and possessing the same lithological characters which it reveals at other localities. I could discover no fossils in it at this point, but I am confident that this bed represents the Potsdam sandstone. The same bed seems to occur all along the mountains from Laramie Peak to Cache la Poudre Creek, underlying the well-known Carboniferous strata, and resting upon the decomposing granitoid rocks which form the nucleus of the first ridge. This rock (the Potsdam) is more or less changed by heat from beneath, but I was able to trace it continuously from the source of the Chugwater Creek to the source of Cache la Poudre, a distance of over 100 miles. It was also seen along the eastern slope of the Wind River Mountains, but did not contain any organic remains.

The above facts show very clearly that in its western extension, the primordial zone of Barrande is represented only by a thin bed of sandstone never exceeding 150 feet in thickness, and that it is seen only in a very narrow outcropping belt near the margins of the mountain crests. The stratified Azoic rocks upon which it rests discordantly, so far as my observations have extended, never reach a very great thickness in the West.

*This is an error. The Tetons are composed mostly of gneissic granite. 1878.
†Am. Jour. Sci. and Arts, vol. xxvi, 276.

III.—CARBONIFEROUS ROCKS (INCLUDING PERMIAN ?).

On both sides of the divide of the Rocky Mountains, so far as our explorations have extended, a series of calcareous, areno-calcareous, and arenaceous beds are seen, which we have referred to the Carboniferous epoch. They vary in thickness at different points. Without specifying localities it will be sufficient to remark that all along the margins of any of the mountain elevations in the far West, these rocks are seen in a more or less inclined position.

Sometimes they are not visible for a short distance (as between the Laramie and Platte Rivers, 20 or 30 miles), but it is plain that they have either been removed by erosion or concealed by more recent deposits. Along the Big Horn Mountains there are alternate layers of sandstone, arenaceous, and magnesian limestones, many of which show oblique laminæ and other indications that their deposition took place in shallow and perhaps turbulent waters. They are here developed to a thickness of 1,000 to 1,500 feet, and incline high upon the sides of the mountains at an angle of 50° to 70°. They contain few fossils, but these indicate rocks of the same age as those in the Black Hills. Along the Laramie Mountains, from the Red Buttes to Pike's Peak, apparently the same limestones are seen inclining against the sides of the elevated ridges at greater or less angles, and on the opposite side of the axis, sloping down to the Laramie Plains, the corresponding strata are seen, though leaning at much smaller angles, usually from 9° to 15°. Along the Sweet Water and Wind River Mountains these rocks are highly developed and incline against the sides of the ridges of elevation, as heretofore described. The corresponding portions are also seen on the west slope of the main range at the sources of Green and Snake Rivers, but not as conspicuously developed, the eruptive rocks predominating. Crossing back over the dividing crest near the sources of the Madison, Jefferson, and Gallatin Forks of the Missouri, we find similar limestones largely developed and covering a considerable area on the eastern slope. Near the junction of the three forks and along Smith's or Kamas River we find them reaching a thickness of 800 to 1,000 feet, often partially changed by contact with igneous rocks beneath. They were also observed around the Judith Mountains, and also about the Bear's Paw and Little Rocky Mountains.

Nowhere in the Rocky Mountain Range, so far as my observations have extended, do the Carboniferous rocks seem to abound in organic remains, and the few usually seen are generally found in a bad state of preservation and comprise a limited number of species. The precise period to which these rocks belong which are so persistent in all disturbed regions is not positively known, the evidence from organic remains pointing to the age of the Coal Measures and sometimes to that of the Lower Carboniferous period; probably both members of the system occur there.

At the foot of the Big Horn Mountains, near the head of Powder River, I observed at one locality a series of beds which indicated the presence of Permian rocks. These beds, which are composed of cherty magnesian limestone, are very much like those already described in Northeastern Kansas, and contain in great abundance some of the same species of fossils as *Myalina perattenuata* and others. I have also seen similar limestones in other localities, but no fossils were detected, and though having a Permian appearance they may belong to the upper portion of the Carboniferous.

The evidence is clear in many localities that prior to the deposition of the Red Marls succeeding the supposed Permian a very great erosion of the surface of the Carboniferous rocks took place. We find, for example, in many localities only a thin representation of the Carboniferous rocks, and again a full development, 1,000 to 1,500 feet in thickness.

IV.—RED ARENACEOUS DEPOSITS.

Overlying the Carboniferous rocks, and equally persistent with them, is a series of red arenaceous marl beds or gypsum-bearing marls, which are coextensive with the upheaved sedimentary formations along the Rocky Mountains. The largest development of these beds which I have observed occurs on the northeastern side of the Big Horn Mountains and on the west slope of the Wind River Mountains, near the source of the Gros Ventres Fork of Snake River. From the Red Buttes, on the North Platte, to Pike's Peak these beds are often removed by erosion or concealed by superficial deposits, but their appearance in numerous places shows very clearly that beneath the surface they occupy a considerable area throughout the country bordering the mountain ranges, possibly extending entirely over the eastern slope. Passing over into the Laramie Plains we find that the red marls constitute the surface formation of the plain country. It has also been shown from Mr. H. Engelmann's explorations that these beds are revealed along the Wasatch Mountains, even south of Lake Utah, furnishing undoubted evidence that they belong to the same great deposit. The fact also that 1,000 to 1,500 feet of red arenaceous beds are seen near the sources of Green River, leads to the inference that they continue southward far down the Green River Valley to that portion which takes the name of Colorado, and are in fact a continuation of the extensive red deposits described by various explorers in New Mexico.

These red beds are also seen under similar circumstances highly developed along the mountains at the sources of the Missouri. There seems to be a change in the lithological characters below the Gate of the mountains, the peculiar red deposits disappearing for the most part, and a series of irregular layers of siliceous limestone with a reddish tinge, and with oblique laminæ, ripple-mark and other indications of shallow-water deposition. It is through these layers of rock that the Missouri River cuts its way from the foot of the mountains to the mouth of High Wood Creek, about 10 miles below the falls. They are also distinctly revealed around the Judith Mountains. Along the Big Horn Mountains thick layers of gypsum occur, but the gypsum beds are by no means coextensive with the red deposits, and indeed are present in but few localities. Near the head of Powder River the aggregate thickness of the gypsum strata is about 100 feet, while near the source of Snake River there is a thickness from 50 to 80 feet. It also occurs to a considerable extent at the foot of the mountains, on La Bonte Creek, a branch of the North Platte.

V.—JURASSIC ROCKS.

These rocks are everywhere revealed, overlying the red deposits just mentioned and possessing an equal geographical extension. Their fullest development and most fossiliferous condition seems to be along the margins of the Black Hills, where they have furnished the most satisfactory evidence of their age. Along the northeastern slope of the Big Horn Mountains this group of rocks presents its usual appearance of gray and whitish calcareous and arenaceous layers, with indurated, somewhat variegated beds of more or less laminated marls, containing in great abundance *Belemnites densus*, *Pentacrinus asteriscus*, a new species of *Ostrea*, *Pecten*, &c.

At Red Buttes we find a fair development of these beds with the same fossils, but as we proceed southward toward Long's Peak, the intercalated laminated marls disappear and the whole formation seems to be reduced to a thickness of 50 to 100 feet, with very few fossils. Along the southwest side of the Big Horn Mountains and the northeast side of the Wind River Mountains we have a thickness of Jurassic rocks from 800 to 1,000 feet containing organic remains in the greatest abundance. Crossing the Wind River Mountains we observed the strata corresponding to those upon the eastern side, with *B. densus*, *Ostrea*, &c. Returning to the eastern slope at the sources of the Missouri, we see occasional indications of their existence, but not so conspicuous as to be readily identified. The age of this group of rocks may be now considered as thoroughly established, so great a number of fossils which appear to be of undoubted Jurassic forms having been obtained.

I have remarked that the older fossiliferous beds doubtless pass beneath the more recent Cretaceous and Tertiary deposits, and occupy a greater or less area underneath the prairie country east of the "divide" of the Rocky Mountains. I have made this inference from the fact that where any elevations occur the complete series of fossiliferous beds are exposed around the axis of upheaval. That I may not be misunderstood by those geologists who have colored large areas Triassic and Jurassic on geological maps of the West, I would say that I have never seen any of the older fossiliferous rocks, from the Potsdam to the Jurassic, inclusive, exposed except in narrow outcropping belts around the margins of the mountain elevations. The Carboniferous rocks occupy a belt from one to two miles wide, and the red arenaceous deposits are exposed over about the same area, while the Jurassic form a zone never more than one-fourth of a mile to three miles in width.

VI.—CRETACEOUS ROCKS WITH SUBDIVISIONS.*

The various subdivisions of the Cretaceous Group in the West were observed at numerous localities. The strata in many places occupy large geographical areas, holding a horizontal position, in others forming a belt or zone of greater or less width around the mountain elevations. No. 1 is a well-marked and distinct division along the Missouri River from De Soto to a point above the mouth of the Big Sioux River in the eastern portions of Kansas and Nebraska and in the South and Southwest. But when we come into the vicinity of the mountain ranges in the Northwest its typical form is wanting, and apparently an increased development of No. 2 only is seen. Along the Big Horn Mountains, No. 2 is 800 to 1,000 feet in thickness, composed of black, plastic clay with several layers of gray and yellowish calcareous sandstones 10 to 50 feet in thickness. Along the Laramie and Wind River Mountains the same characters are shown. After leaving the Missouri, near the mouth of the Niobrara River, No. 3 is never seen presenting its typical marly character. In the vicinity of the Black Hills we saw a series of beds composed of alternate thin layers of arenaceous and argilla-

* The Cretaceous rocks of the West have been divided into five formations, numbered 1, 2, 3, &c. A more careful study of No. 1? may render it necessary to make other divisions.

ceous sediments with *Ostrea congesta* and *Inoceramus problematicus* which may possibly represent No. 3. Along the Big Horn Mountains and from Red Buttes to Cache la Poudre Creek the same fossils were often found and some other indications of its existence, but no well-marked typical beds were seen. It is now well known that *O. congesta* and *I. problematicus* range down into No. 2, so that No. 3 in the West and Southwest may give place to an increased development of No. 2. Nos. 4 and 5 are largely developed everywhere, when not concealed by the overlying Tertiary deposits, especially along the Laramie Mountains and in the valley of Cache la Poudre. In the valley of Wind River all the Cretaceous rocks down to No. 2 appear to have been removed by erosion prior to the deposition of the Tertiary beds, and the characteristic fossils of No. 2 are quite abundant. As we pass over the mountains, we have, inclining from the western slope, 600 to 800 feet of alternations of black plastic clays, arenaceous marls, and beds of sandstones and limestones, with a few seams of carbonaceous matter passing up into calcareous and arenaceous compact rocks. In some arenaceous limestones near the middle of the series, and extending upward, quite abundant fossils were observed, among them a large *Inoceramus*, two species of *Ostrea*, a large *Pinna*, four inches in length, a *Cardium*, and a number of undetermined species, with fragments of silicified wood. The general dip of these rocks is about 20°. These well-marked Cretaceous beds pass up quite imperceptibly into an enormous thickness of Lignite Tertiary. Passing over the dividing crest to the headwaters of the Missouri, we did not observe any indications of Cretaceous rocks until we had descended below the three forks, where we find traces left after erosion. They do not reveal themselves conspicuously until we arrive within twenty or thirty miles of Fort Benton, where the black, plastic clay begins to overlap the Jurassic rocks, with its characteristic fossils, and on reaching Fort Benton the plastic clay is quite homogeneous, and is developed to a thickness of 800 feet. As we proceed toward the mouth of the Judith River and near the Judith Mountains, we find quite thick beds of concretionary sandstone which form the "Stone Walls," "Citadel," &c. It is from these beds that we have obtained a group of fossils which we have referred provisionally to No. 1, but which seem to be specifically distinct from all others in the West. It may be that when this group of beds now referred to Nos. 1 and 2, comprising a thickness of 1,500 to 2,000 feet in this region, are more carefully studied, that several subdivisions will be made, having equal importance with the others. During the past season our route led us along the "divide" between the Missouri and Yellowstone rivers, south of the Judith Mountains, so that we passed outside of any good exposures of No. 1, as well as beyond the limits of the estuary beds at the mouth of the Judith. We must await a more thorough and detailed exploration of this region before we can state with entire confidence the succession of the beds.

VII.—TERTIARY DEPOSITS.

In speaking of the Tertiary deposits of the Northwest, so far as known at the present time, I propose to separate them into four divisions, which will be sufficient for our immediate purposes: 1st. Estuary deposits. 2d. True Lignite beds. 3d. Wind River Valley deposits. 4th. White River Tertiary deposits.

The estuary deposits, of which the Judith Basin may be regarded as the type, are quite remarkable and of a most interesting character. Opinions of a somewhat conflicting nature have been entertained in regard to them, owing to the peculiar character of the organic remains; but recent observations have convinced me that they are all of Tertiary age, and that they are quite widely distributed throughout the far West. The lithological characters of the Judith deposit have already been sufficiently described, and it has yielded many important fossils. A thin series of beds is also found near the sources of the Moreau, Grand, and Cannon Ball Rivers; and at the mouth of the Big Horn River we have a group of beds 800 to 1,000 feet in thickness, with fossils of the same character as those occurring at the mouth of the Judith. The researches of Mr. H. Engelmann, in Utah, have also established the existence of an estuary deposit in the country bordering upon Green River, scarcely less interesting than that of the Judith. These deposits pass up into the true lignite beds without any perceptible line of separation, gradually losing their estuary character and ever after containing only land and fresh-water shells. The lignite strata are chiefly remarkable for yielding in the greatest abundance finely preserved vegetable remains. A few fragments of leaves of Dicotyledonous trees and silicified wood, with very impure lignite beds, are formed in some of the estuary deposits, but no groups to indicate the great luxuriance of vegetation which must have existed during the accumulation of the lignite strata.

The geographical extension of the lignite deposits of the West is now a matter of the highest interest, and, from what is already known, I am convinced that they will yet be found to cover a greater or less area on both sides of the main "divide" of the Rocky Mountains, from the Arctic Sea to the Isthmus of Darien. The estuary and lignite beds seem also to have partaken equally with the older fossiliferous rocks of the influence which elevated the mountain chains. Along the Laramie Mountains and from the Red Buttes to the "divide" between Platte and Wind Rivers, along the Big Horn Mountains, the strata incline at very high angles, 40° to 80°, and in some instances are very nearly vertical. The true lignite strata seem to conform to the older fossiliferous rocks and to have been disturbed by the same influences that elevated the mountain ranges in the vicinity. These Tertiary beds extended over all the plain country to the north, and east of the Laramie Mountains, far to the northward, beyond the limits of our explorations. Crossing the Wind River Mountains, we find them largely developed high upon the western slope, dipping at a high angle, from the Wind River Range on the one side and the Wasatch and Green River Mountains on the other.

Throughout the Wind River Valley is a series of beds, of great thickness, which seem to be intermediate in their character between the true lignite beds and the White River Tertiary deposits. We first observed them gently inclined near Willow Springs on the North Platte, and thence westward toward the Sweet Water Mountains and near the "divide" between the North Platte and Wind River they reach a thickness of 400 feet. From this "divide" throughout the Wind River Valley they occupy the greater portion of the country, and, though inclining in the same direction with the older strata, the beds do not dip more than 1° to 5°. They differ from the other deposits in the great predominance of arenaceous sediments and in the absence of vegetable remains, but they contain fragments of turtles and numerous fresh-water and land shells of the genera *Helix*, *Planorbis*, *Vivipara*, &c. The entire thickness of these deposits may be estimated at from 1,500 to 2,000 feet. From the fact that these deposits do not conform to the true lignite beds and that detached portions are seen lying upon the sides of the mountains but slightly inclined, while the corresponding beds are shown in the valley below, we infer that they were accumulated long before the mountains were raised to their present height, or perhaps during the gradual process of elevation. This is especially shown at the upper end of the Wind River Valley. Passing over the Wind River Mountains we again see them holding the same position on the western slope, and possessing the same lithological characters. While the lignite beds on the west side of the "divide" incline at a large angle, the more recent beds, although in some places occupying the very crest of the mountains, seldom incline more than 3° to 5°.

The most interesting additional facts which we have obtained in regard to the White River Tertiary beds, are their geographical extension and the evidence of their age in relation to the lignite deposits. We can now show beyond a doubt that the former must have been accumulated long since the latter. We have ascertained that they extend southward along the Laramie Mountains to Willow Springs within 10 miles of Cache la Poudre; that they also extend up the North Platte to the Box Elder Creek, and even beyond are small outliers, showing that much has been removed by erosion. Passing over into the Laramie Plains we find at the source of the Box Elder and extending over to the head of Bates Fork a large development of this Tertiary, and it also reaches far westward to the Medicine Bow Mountains. We also know from the observations of Dr. Hines that it occupies a considerable area among the Sweet Water Mountains, extending over into the Green River Valley. We have along the North Platte the overlapping of the White River beds upon the lignite strata, thus affording the evidence of superposition for their relative age. The same fact was noticed between the North Fork of the Cheyenne and the head of Cherry Creek, where beds of marl and limestone containing *Planorbis*, *Limnea*, &c., the same as are seen in the Bad Lands proper, repose upon true lignite Tertiary strata. Again, while the White River beds hold for the the most part a horizontal position, those of the lignite Tertiary are often much disturbed. Near the Black Hills the former seem to have been elevated to a considerable height by the upheaval of the mountains, but they do not in any case incline more than 1°, while north of the Black Hills the lignite beds dip 5° to 10°. Along the Platte I have seen the former inclining 5°, especially on La Bonte Creek and about 15 miles east of the mouth of that creek. Often the beds seem to have been raised up several hundred feet above their original position, without inclination, resting upon the upturned edges of the lignite beds which we have before observed, partook equally of the disturbing influences which have given so great an inclination to the older fossiliferous rocks. Along the Big Horn Mountains and the North Platte the lignite beds sometimes incline from the foot of the mountains 80°, and often the influence of the elevatory power has affected them far out into the plain country.

In the above accounts of the Tertiary deposits of the West we have shown that the older members are clearly separated into four divisions exclusive of the Pliocene deposits of the Niobrara. Let us examine the evidence in regard to the age of these deposits. If we study the upper portions of Cretaceous formation No. 5 when not removed by the erosive power of water to any great extent, we then observe from the time we pass from No. 4 to No. 5 a gradual change in the sediments, and other indications of a slow approach to shallow water; arenaceous sediments begin to take the place of argillaceous, so that we have alternate thin layers of sand and clay, the sand continuing to increase until the upper part becomes a yellow ferruginous, coarse sandstone, with most conspicuous examples of ripple-mark and oblique laminæ. As the waters of the Cretaceous sea were gradually receding, toward the Atlantic, on the one side, and toward the Pacific on the other, remnants were left in the form of lakes, estuaries, &c., which now afford us the last indications of marine and brackish water deposits in the central portions of the West. In these deposits we have first a mingling of brackish and fresh water forms, gradually passing up to pure fresh water and terrestrial species, with no return to the marine condition again.

In the upper part of the Cretaceous formation No. 5, on the Moreau, we find the *Ostrea subtrigonalis*, and in the Judith deposits a form occurs in the greatest abundance, which is undistinguishable from it.

We have also mentioned the fact that the fossils of upper part of No. 5 seem to have existed upon the verge of the Tertiary period, that they sometimes present peculiar forms more closely allied to Tertiary types than Cretaceous, and were it not for the presence of the genera *Baculites*, *Ammonites*, *Inoceramus*, &c., which are everywhere supposed to have become extinct at the close of the Cretaceous epoch, we would be in doubt whether to pronounce them Tertiary or Cretaceous. These facts would seem to indicate a foreshadowing of the Tertiary era, and that the transition from one great period to the other was gradual and quiet, the change in the physical conditions being ultimately sufficient to destroy the Cretaceous fauna, and bring into existence that of the Tertiary. Again, in numerous localities where No. 5 is fully developed and a large thickness of Tertiary deposits is superimposed, so that near some of the mountain elevations I have found it difficult to draw the line of separation, no apparent physical break occuring in the sediments.

Will not these statements go far to show that the estuary deposits ushered in the dawn of the Tertiary epoch and induce the belief that they belong to the first part or Eocene period? This point is an important one to establish, on account of its bearing upon the history of the physical development of our western continent.

The estuary deposits soon lose their marine and brackish character and gradually pass up into the true lignite strata, of purely fresh-water origin, thence by a slight discordancy into the Wind River Valley beds, which give evidence of an intermediate deposit between the true lignite and White River Tertiary beds. Then come the White River bone beds, which pass up into the Pliocene of the Niobrara by a slight physical break, and the latter are lost in the Yellow Marl or Loess deposits. I have estimated the entire thickness of Tertiary rocks in the Northwest at from 5,000 to 6,000 feet, and their interest will be appreciated when I venture to suggest that by thorough investigation they will doubtless reveal in a most remarkably clear manner the history of the physical growth and development, step by step, of the central portion of this continent. I shall treat this subject more fully in a future paper, and would refer to the forthcoming report of Captain Raynolds for the details of the facts sustaining my opinions.

We have no evidence, so far as I know, of long continued deep-water deposits in the West, until far up in the Cretaceous period. If we examine the Potsdam sandstone we shall find that where it reaches its greatest force the lower portion is composed of an aggregation of quartz pebbles cemented with siliceous matter, and as we pass upward, we find it arranged in thin layers quite compact with fucoidal markings, ripple-mark, &c. Everywhere are most abundant examples of oblique laminæ of deposition and ripple and wave markings—evidences of shallow waters.

During the long period that elapsed between the deposition of the earliest part of the Silurian epoch and the commencement of the Carboniferous we have reason to believe that dry land prevailed over a large portion of the West. The Carboniferous epoch commences with thin layers of arenaceous deposits, gradually passing up into homogeneous siliceous and calcareous beds. The latter are never more than from 20 to 50 feet in thickness, and then the arenaceous sediments begin again to predominate, and all the proofs of shallow as well as turbulent waters are shown. We then pass up through the red arenaceous deposits and Jurassic beds, and find no rocks that indicate deep water deposition. Cretaceous formation No. 1 commences in many places with a considerable thickness of an aggregation of water-worn pebbles passing up into thin alternate layers of arenaceous and argillaceous sediments with thick beds of sandstone with ripple markings and oblique laminæ, then gradually ceases in No. 2, and through Nos. 2, 3, and 4, the sediments indicate that they were accumulated in comparatively deep and quiet waters. No. 2 is a black plastic clay, No. 3, gray marl, and No. 4, a dark indurated, sometimes laminated, clay, with many calcareous concretions. In No. 5 we gradually approach indications of shallow water until dry land appears, as already stated.

It will not be possible at this time to mention in detail all the oscillations of surface and other physical changes to which we have reason for supposing the country was subjected during all these periods. It is sufficient for our present purpose to show that, except during the Middle Cretaceous epoch, no long-continued periods of quiet water prevailed in these ancient western seas.

The evidence appears to me to point to the conclusion that a much milder climate prevailed throughout the western portions of our continent, during a greater part of the Tertiary period, than that which exists in the same latitudes at the present time. The organic remains appear to indicate a subtropical climate, or one similar to that of our Gulf States. Near the close of the Cretaceous epoch the waters of the great Cretaceous sea receded toward the present position of the Atlantic on the one side, and toward that of the Pacific on the other, leaving large areas in the central portions of the West, dry land. These areas were of course in close proximity to the sea, and comparatively but slightly elevated above the ocean waters. In regard to the mollusca which have been found quite abundantly entombed in the lignite-bearing strata, it is an interesting fact that the most nearly allied living representatives of many of these species are now found inhabiting the streams of Southern Africa, Asia, China, and Siam, apparently indicating the existence of a tropical climate in these latitudes at as late a period as the Tertiary epoch.*

Again, the luxuriance of the flora which has been so perfectly preserved in the lignite strata of the West point to the same conclusion. It is true that until recently no species have been found which belong exclusively to a tropical vegetation, but during our last expedition we obtained a species of true fan-palm, very closely allied to *Sabal lamonis*, figured by Dr. Heer in his "Flora Tertiaria Helvetiæ." "The most northern limit of palms is that of *Chamærops palmetto*, in North America, in latitude 34°–36°, and of *Chamærops humilis* in Europe, near Nice, in 43°–44° N. latitude."† The true palms of our present day are considered as having their native land within the tropics. That this or a similar condition of climate continued throughout the accumulation of the Wind River Valley deposits may be inferred from their molluscan remains, which are more nearly allied to tropical forms.

Again, we have in this region, as before mentioned, an extensive area occupied by the lignite-bearing strata. There are from 30 to 50 beds of lignite, varying in thickness from 1 inch to 7 feet. Over all this great area there are at the present time no large forests, no timber except that which skirts the streams. We now know that during the Tertiary period vast forests of timber must have covered many portions of the far West from the abundance and variety of the vegetable remains preserved in the rocks. Silicified trunks of trees, 50 to 100 feet in length and 2 to 4 feet in diameter, and stumps which indicate gigantic forest trees occur abundantly over hundreds of square miles along the Missouri and Yellowstone Rivers. Professor Henry and other meteorologists have arrived at the conclusion, from a vast number of well-authenticated facts, that the absence of forest trees on the great prairies of the far West is due to the want of moisture, which is well known to prevail all along the eastern slope of the Rocky Mountains. The prevailing winds are now known to come from the west and northwest, and, as the currents of air laden with moisture from the Pacific ascend the western slope of the mountains, become condensed and deposit their burdens for the most part before reaching the eastern slope.

Professor Henry, in his paper on Climatology, contributed to the Patent Office Report for 1856, says: "The return westerly current, sweeping over the Pacific Ocean, and consequently charged with moisture, will impinge on the Coast Range of mountains of Oregon and California, and, in ascending its slopes, deposit moisture on the western declivity, giving fertility and a healthful climate to a narrow strip of country bordering on the ocean, and sterility to the eastern slope. All the moisture, however, will not be deposited in the passage over the first range, but a portion will be precipitated on the western side of the next, until it reaches the eastern elevated ridge of the Rocky Mountain system, when, we think, it will be nearly, if not quite, exhausted." We are now supposing that the climatic conditions—winds, currents of air, &c., did not differ to any great extent during the Tertiary epoch from those which prevail in the same latitudes at the present day. We therefore venture the suggestion that up to the time of the accumulation of the Middle Tertiary deposits the lofty barrier of the Rocky Mountains did not exist.

WASHINGTON, D. C., *January* 20, 1861.

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* See Memoir by F. B. Meek and F. V. Hayden in Proc. Phila. Acad., June, 1856.

† Lindley's Vegetable Kingdom, p. 136.